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TRAIL CONDITIONS AND MANAGEMENT
IN THE ROCKY MOUNTAINS, ALBERTA

by



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A THESIS

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ABSTRACT

The increasing number of visitors to Jasper National Park, Alberta, in the last decade has resulted in a notable increase in the use of hiking and riding trails. Any extent of such tourist use of a trail will result in alteration of the terrain and, eventually, deterioration in the soil, vegetation, and trail condition.

Pedestrian and equestrian traffic both remove vegetation but have different effects upon the trail dimensions and the environment. Hikers trample and compact the soil, decreasing the amount of air and water entering the ground, compressing and harming the plant roots and adversely affecting revegetation. Alternatively, horses loosen and move the soil. Because compaction on horse trails is less than on hiking trails, revegetation of horse trails will occur much sooner after use has ceased than on hiking trails.

This study examines pedestrian and equestrian trails in the area of Folding Mountain just outside the Jasper National Park boundary. Trail dimensions, soil compaction, and effects of use are discussed. The results are compared to those conditions found on some trails in Jasper National Park. Suggestions are made for optimum development and management of intensively-used paths in the mountain parks based on the findings of this study.

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CHAPTER . 1

INTRODUCTION

With advances in modern technology, increased income, decreased work hours, population congestion in urban areas and the demands of modern living, recreation has become much more important than ever before. Recreationists and vacationers travel to municipal, provincial, and national parks for weekends and extended holidays. Hiking and mountain climbing have become increasingly popular summer sports, and ski-touring along back-country trails has encouraged increased use of park trails during the winter. Since 1962 there has been a 30 percent annual increase in Canadian national park visitation. The average annual visitation increase in Jasper National Park is 10 percent¹.

1.1 RECREATIONAL USE OF PARKS VERSUS PRESERVATION OF WILDERNESS

Such a marked increase in park use has created conflicts among aspects of the National Park policy. The purposes of the National Parks were stated in the National Parks Act of 1930. The Act specifies that:

The Parks are hereby dedicated to the
people of Canada for their benefit, education,
and enjoyment.....and such parks shall

1. Personal Communication: B. Anderson, Chief Warden,
Jasper National Park, July, 1972.

be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations¹.

Recreation and preservation of wilderness areas are not compatible since the natural environment cannot be preserved under intensive recreational use.

The general terms of the Act leave much leeway for park use, international advertisement of scenery and facilities, and development of visitor service centres. However, with increasingly intensive use, the park lands are not being maintained unimpaired. Despite the provision for recreational use of the National Parks, the preservation of the natural environment should remain as the primary objective.

It is expected that use of the National Parks will continue to multiply. It follows that adverse effects on the environment will also be increased. The maintenance of a relatively unimpaired environment, therefore, depends upon either restrictions on use, or development of recreational zones in such a way or in such an area as to minimize possible degradation and damage. It is the investigation of damage in regard to trails and footpaths that is the purpose of this study.

1. Canada Department of Northern Affairs and Natural Resources, National Parks Branch, National Parks and Historic Sites Services, The National Parks Act, Ottawa, 1956, 1930, c. 33, s. 4.

1.2 HIKING AND RIDING TRAILS - JASPER NATIONAL PARK

In Jasper National Park and the adjacent eastern slope foothills of the Rocky Mountains in Alberta there are over 1100 km of established hiking and riding trails. Some of these were originally used by Indian travellers and subsequently by the pioneers as routes through to the west. Other trails were cut through the forests expressly for exploration, and still others were carved especially for those seeking the wilderness and back country. Many of these trails are now used by hikers, outfitters, wardens, and cross-country skiers. Some of the old routes have become overgrown, and are rarely used. Those trails providing a scenic or passable route to a point of interest or alpine hut, and those whose length is attractive as a day or overnight trip are used most frequently by back-packers and horse riders.

Of these mountain trails, some are extensively used and others receive very few visitors per year. Before venturing into the back-country, it is imperative for safety and rescue reasons to register the number of persons in the party, the expected route, and the length of stay. In Jasper National Park, check-in lists are provided at all the Warden's stations, at the head of the Astoria River trail, and at the Warden Service office in Jasper townsite. However, these provisions are not adhered to by all trail users. Although check-in facilities are available, the number of users is not regularly compiled by Park personnel.

There are no records of the number of horses passing over the trails. However, it is known that there are favourite as well as scarcely-used areas within and surrounding the Park, but their use can only be described qualitatively.

Although a statistical break-down of individual trail use is unavailable, there is a record of cumulative hiking registrations. These data from 1963 - 1971 are shown in Figure 1.

The extent of use an area or trail receives depends upon a number of factors. The degree to which the area or attraction is publicised and the aesthetic appeal of the area and access trail are important in drawing visitors. The ease with which an area can be traversed, access from main transportation routes, and distance along the trail to a specific attraction are also essential factors which determine the amount of use a trail receives.

1.3 GENERAL EFFECTS OF HIKER AND HORSE USE OF TRAILS

It is indicated in the National Parks Policy¹ that use of trails on foot or horseback is to be encouraged in the National Parks. Any trail development is to be confined to those areas not reserved for research purposes, and is to conform to the rudimentary nature of other wilderness

1. National Parks Policy, National and Historic Parks Branch, Canada Department of Indian Affairs and Northern Development, Ottawa, 1969. p. 8, 14.

ANNUAL HIKING REGISTRATIONS
IN JASPER NATIONAL PARK 1963 - 1971

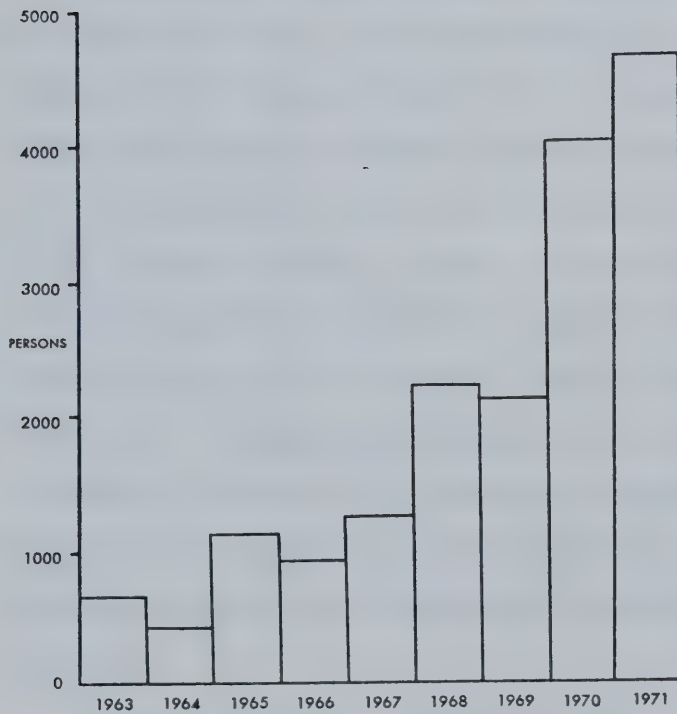


Figure 1

Source: Superintendent's Annual Report. 1971. Visitor Use Statistics, Jasper National Park.

facilities such as directional signs, stream crossings, and campsites. Although it is general policy to separate pedestrian and equestrian traffic on the trails, this is not upheld in all cases. One trail in Jasper National Park which is heavily travelled by both hikers and riders and has no use restrictions is the Astoria River - Tonquin Valley trail system.

Since each trail differs in the type and amount of use to which it caters, each is ecologically and aesthetically altered in a different way and to a different extent. Some rarely-used trails require little or no maintenance, while heavily-frequented trails have become so physically impaired as to require asphalt, gravel, or wood-chip pavement, culverts, bridges, primitively equipped campsites, and restrictions on the visitors' choice of camp and fire locations. A physically damaged area results in a decrease in aesthetic appeal and a resultant reduction of use and indifference toward its maintenance until such time as the area has either been cleared and improved or has rejuvenated naturally.

Once an area and its access trails become popular, it is soon evident that the rules of the trail are ignored by many, and general deterioration of the route results. Long stretches of switchbacks up a steep slope - particularly arranged for greatest ease in ascending an incline - are soon disregarded in favour of a faster short-cut perpendicular to the trail, and straight up the hill. This

alternate route soon becomes used enough to be obvious, and its use continues to increase. This rearrangement from a considerably more level path to a sometimes vertical drop can, and often does, lead to a rapid wearing away of the vegetative cover and, because of the slope, a downhill movement of earth and stones. A deep incision may soon result if the path passes through an area of relatively deep or fine soil. This type of alternate route is dangerous in that a hiker's footing is much less secure on such steep inclines, especially when the ground is wet. A marked incision such as a deep vertical path causes unnaturally fast melt water and rain runoff from the surrounding ground in the spring and early summer. Also, the trench may tend to gradually widen as the soil on its side gives way. This type of degradation is more affected by horses than by hikers. The horses, if allowed to follow a short-cut or any inclined trail, tend to loosen the soil with their hooves, especially when shod, and promote mass movement. This incision becomes much more evident as the slope of the trail increases. Thus, it is important in planning a trail layout to consider variations of incline of the terrain, the amount and nature of the soil, and the type of use the trail will receive.

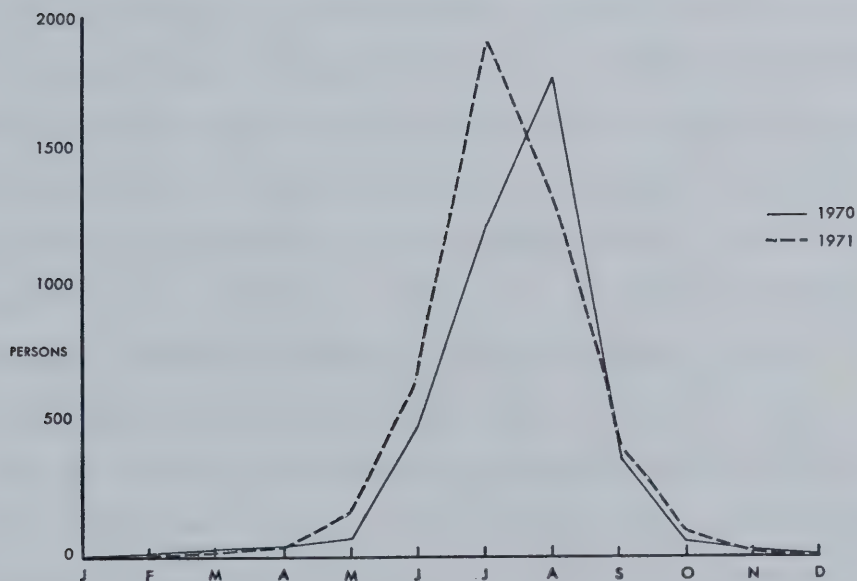
Impoverishment of an area can result from extended or sudden intense use and disturbance by horses or hikers. The type and vulnerability of the ecosystem dictates the type and extent of use which can be supported, but consis-

tent trampling is usually harmful. This is especially apparent on trails in the Jasper Park region since traffic is confined to the designated hiking and riding paths. The concentration of trail traffic during a short period of time is a result of snow in the high country which often lingers until the beginning of July, and the tourist use of the trails. The tourist traffic is concentrated in the two-month summer season (Figure 2), and it results in a very high intensity of trail use and trampling. Excessive use will therefore impoverish the trail route. The extent of this damage is related to the carrying capacity and vulnerability of the ecosystem through which the trail passes.

It is clear that human traffic results in increased compaction of soils. The concentration of continued use on a confined area in particular results in soil compaction (Westhoff, 1967). Lutz (1945) says that the nature of the soil influences the amount of compaction - fine-textured soils compacting to a greater extent than coarse soils.

Heavy recreational use of any hiking area also results in a decrease of vegetation on and alongside a trail and increased soil compaction. The resultant suffocation or desiccation of roots can lead to elimination of the adjacent vegetation. Michaud (1967) found that the most damaging alteration in the natural condition of the forest occurs under intensive recreational use. Kraus (1967) observes that crowds of people have the effect of compacting the soil

MONTHLY HIKING REGISTRATIONS
IN JASPER NATIONAL PARK - 1970, 1971*



*Peak displaced because of
forest fires in August, 1971.

Figure 2

Source: Superintendent's
Annual Report. 1971.
Visitor Use Statis-
tics, Jasper
National Park.

and of exposing and damaging roots, so that severe harm may result.

1.4 EQUESTRIAN TRAILS

Most mountain trails do entertain equestrian traffic. However, trails serviced by outfitters or guides for tourist and hunter use, and those travelled by riders with their own horses are altered differently than those used strictly by pedestrians. Generally, pedestrian trails show the effects of trampling by an increased soil density and the levelling of the path-way. Soil permeability is greatly decreased, and there is a significant reduction of vegetation on the trail because of the inaccessibility of air and water through the dense soil to the plant roots. Hiking trails may be several metres in width as a result of walkers' general tendency to walk in pairs or groups. Apart from trampling of vegetation, hiker use of trails results in removal of plants and stones by collectors, destruction of trail-side flat areas by use as camp sites, gathering of firewood from lower branches of trees (the gathering of wood is especially evident and destructive near timberline where wood is scarce and the stunted vegetation is slow to recover from misuse), and the dumping and burning of garbage.

Equestrian trails generally have a less compacted and often more incised path. A shod hoof tends to loosen and move the soil rather than flatten and harden it. On fine-soiled trails, this loosening is most obvious. The soil is

kept aerated and unconsolidated. Hooves kick clods of earth off the path as well as carry it along the trail. On slopes the loose soil is most susceptible to movement down-slope, by running water, and as a result of being displaced by a sharp hoof. Therefore, horse trails develop as trenches which may continually deepen and widen depending upon intensity of use, soil type, and slope. Slope in particular is a most determining factor of trench deepening and soil compaction. With a levelling of slope, the incision decreases and soil compaction increases.

There are significant differences between equestrian trails traversing treed areas and those crossing alpine meadows. Confined within a forest, horses are forced to follow an established path delimited by trees. Trampling is thus limited to one track which becomes intensively used. On alpine meadows, however, movement is not impeded, so the horses' unchanneled walking reduces the intense impact on one trail. The use is distributed over several tracks, or is totally unconfined and spread extensively over meadows. Damage to alpine plants and changes in soil characteristics are reduced since limited movement over any single path does not necessarily result in significant degradation. This unchanneling is also evident with hikers. Trails often disappear as they reach meadows where hiking need not be restricted to one pathway.

1.5 SOIL COMPACTION

Lull (1959) defines soil compaction as the packing

together of soil particles by forces exerted instantaneously at the soil surface. This results in an increase in soil density through a decrease in pore space. The reduced infiltration capacity increases surface runoff and erosion especially in mountain areas which are steep and receive a high amount of precipitation.

Most literature on the subject of soil compaction deals with the effects of vehicular traffic and the resultant reductions in plant vigour because of alterations of the soil characteristics. Rosenberg (1964) and Foil (1965) examined the growth of various plant species in soil compacted both by vehicles and artificial means in a laboratory and found that increased mechanical impedance reduces the chances for establishment and growth of plants.

Compaction is not only a result of vehicular traffic. Trampling has also been found to greatly alter the soil structure and to leave an almost impermeable compacted soil layer on the ground surface through which air, water, and plant roots cannot penetrate. Lutz (1945), Willard (1960, 1963, 1967), Kraus (1967), Westhoff (1967), and Marr (1970) have observed and measured the effects of pedestrian trampling on soil and vegetation and found their effects harmful. Little information exists concerning the effects of trampling on soil compaction and erosion since there are many variables such as climate, soil type, slope, plant species, and intensity of use. The information available is reduced in value as a result of varying methods of qualitatively

and quantitatively recording data and the variety of equipment used in field and laboratory measurements.

The compactibility of soil varies with the water content (Black, 1965). Pulverized, air-dry soil neither compacts readily nor reaches a high density. With the addition of water the tendency of the soil to compact increases until the optimum water content for soil compaction is reached. After this optimum point, the soil compaction decreases with an increase in the water content. The optimum water content for soil compaction tends to increase as soil texture becomes finer. For any one texture and density, the supporting capacity will fluctuate with changes in the moisture content.

Under wet conditions, silt loam soils have the lowest weight-supporting capacity. Clays and sandy loams have the greatest capacity, while stony glacial drift does not compact at all (Lull, 1959).

1.6 SOIL COMPACTION ON TRAILS

Trails bare of vegetation may be in this condition because soil compaction equals or exceeds the critical compaction limit for plant growth. This condition on pedestrian paths may not fit equestrian paths, however. On level equestrian trails soil compaction may approximate that of pedestrian trails, but where trails slope at such a degree that erosion has incised the path, they may have a low compaction reading as compared to the level trail. The lack of vegetation here is due to the constant movement of soil

by hooves and erosion. Readings at such points may show that although the compaction of the site is below the upper limits for initiating and maintaining plant growth, the site factors of slope and use inhibit vegetation establishment.

Raney et al. (1955) found that implement traffic and livestock trampling may cause soil horizons of high bulk density to form. Fine-textured soils are most easily compacted by an induced force, root growth being restricted when bulk density exceeds 1.4^1 . Read (1957) found statistically significant differences between soil compaction on used and unused sites. On one area he found the average bulk densities to be 1.22 on a used site and 1.01 on an unused site. Corresponding total pore space measurements were 51.7 percent on trampled soil and 57.3 percent on protected sites.

1.7 TRAMPLING

The extent to which soil is compacted depends not only on the terrain, frequency of travel over the soil, type of soil, and water content, but on the type of equipment or pressure exerted by the trampling animal or individual. Soils compacted by trampling display reduction in the permeability rate, an increase in bulk density, and a decrease in

1. Bulk density is a ratio of the oven-dried mass to the volume of the sample in the field expressed in gm/cc.

macroscopic pore space (Steinbrenner and Gessel, 1955). Read (1957) notes that the effects of trampling are not easily observed, but unfavourable conditions for tree growth and vigour are created especially where trampling is restricted to small areas. There is a lack of useful information about the tolerance limits of trampling disturbance (Packer, 1953).

1.7.1 TRAMPLING BY LIVESTOCK

Very little information is available on the ground pressures exerted by livestock or about the area disturbed by trampling in relation to the number of stock. However, it has been stated (Lull, 1959) that trampling by livestock on level ground exerts pressure at least equivalent to that of heavy tractors. Blair (1937) cited calculations showing that an ordinary farm horse exerts pressure of 2.0 to 4.0 kg/cm² if the ground is hard enough for the whole weight to be taken by the shoes. According to F.A.O. (1959) a horse exerts a pressure of 1.4 kg/cm². These figures are for static loads. During movement, pressures are greater as body weight is distributed over a smaller bearing surface since animals may put their entire weight on one foot thereby increasing the aforementioned figures at least by a factor of 4. The degree of disturbance by stock on a trail increases directly with the slope steepness until the slope becomes so steep as to be inaccessible, and thus escapes trampling degradation.

1.7.2 TRAMPLING BY MAN

Although walking might be considered a minor disturbance in comparison to the use of trails by horses, considerable ground disturbance and pressures are produced by man's trampling. Infiltration of air and water in a trampled area are only a fraction of that on unused areas. According to Meinecke (1929) excessive tourist travel in the California redwood parks compacted soils normally loose and elastic. After being trod upon for some time such soils become firm and dense. Finally, a hard surface sheet formed thus reducing or eliminating the normal air and moisture exchange with the atmosphere. This impermeable ground layer shed water readily, thus increasing surface flow and erosion. The soil below this layer became abnormal, offering unfavourable living conditions to plant roots. Trampling compaction on roads, footpaths, and trails often remains such that vegetation is absent for many years after travel over them has ceased.

Lull (1959) found that a 70 kg man exerts pressure of 1.94 kg/cm^2 (27.6 lb/in^2) for one foot or 0.97 kg/cm^2 (13.8 lb/in^2) if standing on both feet - which he is not while walking. Depending upon the shoe type and person's size, the following pressures in pounds per square inch have been documented by Lull (1959):

Table 1 Trampling Pressure

Area of bearing in ² surface ₂ (cm ²)	Weight lbs. (kg.)	ground pressure ₂ lb/sq.in. (kg/cm ²)
22.6 (145.8)	135 (61.2)	6.0 (.42)
24.0 (154.8)	150 (68.0)	6.2 (.43)
25.2 (162.6)	165 (74.8)	6.5 (.46)
12.3 (79.4)	102 (46.3)	8.3 (.58)
10.7 (69.0)	128 (58.1)	12.0 (.84)
12.1 (78.1)	160 (72.6)	13.2 (.92)
6.9 (44.5)	108 (48.9)	15.7 (1.09)

The effects of trampling on soil compaction have not yet become understood because of the dearth of research before and after trampling has taken place on a previously unused site. The trampling pressure, frequency, proportion of scheduled use vs. grazing use, effects on infiltration and runoff, and their duration, vegetation and soil types and tolerance must all be studied in order to recognize all causes and effects of trampling and soil compaction.

1.8 SOIL EROSION

The disturbance of soil caused by livestock trampling has long been known to be an important factor contributing to accelerated erosion and summer storm runoff on western forest and range lands (Packer, 1953). Running water is a principle cause of soil erosion on trails stripped of a vegetative cover. All levels of trampling disturbance increase the amount of overland flow and soil erosion above that on undisturbed sites (Packer, 1953). When soil on an inclined trail becomes saturated by water flowing from

streams, springs, or snowbanks, erosion or slumping may occur. The water flowing down-trail removes soil and fine gravel, often leaving the trail as a channel for future intermittent streams. In places where streams cross trails, the stream may abandon its channel and flow down-trail. The chances of this happening are determined by trail slope and orientation. A trail extending straight down-slope provides an excellent channel for running water while a trail running parallel to the contours across slope will not provide a suitable channel (Root and Knapik, 1972). If the flow of water is not sufficient to itself erode the trail, the soil may become saturated to the point where trampling will cause maximum damage. On heavily trodden and compacted footpaths the seepage of water into the ground is impaired. Surface runoff flows as the most erosive component of runoff by detaching soil particles and transporting much soil downslope.

1.9 REASONS FOR THE STUDY

An investigation of the trail condition under pedestrian and equestrian use would provide a statement of the effects of this use on the trail dimensions and aesthetic appeal of the area through which the trail passes. The increased use of trails during the past decade is demanding increased and improved management and maintenance of mountain paths. Without a knowledge of the relationships between the nature and amount of use, alterations to the

soil and drainage conditions, and the effects on trails of varying slope, efficient trail management is not possible. This knowledge combined with an investigation of the distribution of recreational use of the parks' trail systems could result in a decreased use intensity in heavily used areas. A dispersal of traffic onto the less travelled trails and scrutiny over placement and management of newly-developed trails may eventually decrease damage and increase carrying capacity in the recreational zones of the Rocky Mountains.

1.10 LIMITATIONS OF THE STUDY

Any study of footpath or trail use could include a multiplicity of variables. The type and extent of trail use, its geology, soil type, vegetative cover, slope, aspect, climatic conditions, wind and water erosion, and drainage are all factors affecting the trail environment. Complete coverage of all the involved forces and ecological characteristics would require involved and extensive field study and would produce volumes of findings.

Thus, the need for economy in scale demands a restriction to only a few of the aforementioned influences. A preliminary study on trails revealed that pedestrian paths were often over one metre wide, but not severely incised below the surrounding ground level, were without vegetation, and had considerably levelled and compacted soil. Conversely, equestrian trails displayed less width but greater

depth, and the soil was usually loose and friable. It was observed that horse path depth increased and soil compaction decreased with an increase in the degree of trail slope. In order to determine the dimensional characteristics of hiking and riding trails, a system of trails was chosen where factors of climate, soil, geology, and vegetation were relatively uniform through the area. In this way, the factors other than type of use, trail depth and width, and soil compaction were not considered in detail, as a regional uniformity was assumed.

Observations on trails inside Jasper National Park were made to determine whether there was comparability between trails receiving similar use and in the same climatic and vegetational zone as those in the main study area.

1.10.1 REGIONAL LIMITATIONS

Although several trails were studied, the results and conclusions will pertain only to those trails situated along the Rocky Mountain east slopes in western Alberta. Because of a great variability in climatic factors, soil conditions, and use characteristics along trails located in different regions, only general statements of trail lay-out or management may be applied to other areas. Although identical trail lay-out practices might not be feasible elsewhere, trail management techniques meant to improve the movement of tourist traffic in recreation or protected areas can be

applied on a broad scale.

1.10.2 SEASONAL LIMITATIONS

The length of the field season during which research for this study was carried out did not permit any opportunity for testing the chances for revegetation of trampled pedestrian and equestrian trails. The soil compaction measurements provide an indication of the soils' revegetative ability and are a source of information on which a further study of soil density and resultant plant colonization and vigour could be based.

A study carried out over several years could more accurately state and predict trail use and damage. Winter conditions on trails at different elevations and in a variety of ecosystems, snow bank locations, and runoff patterns are important factors which should be included in any trail study. Use of the trails by winter sports-people and wildlife are often ignored in outdoor studies because of winter inaccessibility of the study area, but efforts should be made to observe these types of trail traffic. Climatic characteristics, and the vegetation cover varying during the year and over a number of years could be observed at different times over the course of the seasons to best determine all factors which contribute to alpine and sub-alpine trail erosion and degradation.

Another seasonal limitation inherent here was the occurrence of unusually inclement spring and summer weather. This impeded observation of trail conditions under normal

climatic and use conditions. Late in the summer of 1971 much mountain trail use ceased for several weeks because of the forest fire hazard resulting from hot and dry weather during the first weeks of August.

1.11 FIELD SEASON

The Folding Mountain and Astoria River - Tonquin Valley trails were first observed for this study during July and August, 1971. Hiking and riding habits were noted, general trail conditions recorded, and preliminary measurements of trail depth and width taken. Soil compaction measurements were all taken during July and August, 1972. All other trails mentioned in this study were visited during the summer of 1972.

1.12 LITERATURE REVIEW

Literature on the use and degradation of trails by human and animal traffic is scarce, but with an increased interest in National Park and wilderness areas there has begun a series of trail studies both on impact and user behaviour. In 1972 and early 1973 various Canadian federal agencies completed or were still researching trail use in the western mountain parks. Personal contact with the persons involved has been the only communication from these studies to date since publications are not yet available.

The recreational impacts of the various products of tourism on California parks, landscape, Canadian National Parks, countryside adjacent to highways, vegetation, and

alpine tundra ecosystems have been studied and documented by Meinecke (1926, 1929), Laing (1961) and Edwards (1967), Coleman (1967), Kraus (1967), Westhoff (1967), and Willard and Marr (1970) respectively.

Recreational carrying capacity of protected areas is discussed by Wagar (1964), Lucas (1964) and Lime (1970) on the Boundary Waters Canoe Area between Ontario and Minnesota, and by Stankey (1971) who discussed the maintenance of recreation quality through proper management for the highest capacity. Michaud (1967) observed the ecological impact of use on the American forest recreation areas.

The effects of human and animal trampling and soil compaction in camp and picnic grounds has received little attention other than short qualitative descriptions. Lutz (1945) defined fine-textured soils as the most vulnerable to recreational damage. The effects of camping on vegetation in Riding Mountain National Park were listed by Bailey and de Vos (1970), and Dykema (1971) noted similar damage in the Southern Sierra Nevada campgrounds. Soil compactibility, plant and seedling response to compaction, soil density and erosion, and restoration of compacted soils are discussed by Felt (1965), Foil (1965), Rosenberg (1964), Free, Lamb and Carleton (1947), Gardner (1962), and Garner and Telfair (1954). Compaction by animal traffic has been studied and measured by Stoeckler (1959), Tanner and Mamaril (1959), and Federer, Tenpas, Schmidt, and Tanner (1961).

Track-making by man and domestic animals and the variability of effects on different ecosystems were observed on British pastures and grasslands by Thomas (1959, 1960) Bates (1950) reviewed the characteristics of footpaths and animal tracks. Willard (1960, 1963) and Willard and Marr (1970) studied the effects of human activities on alpine tundra trails in Rocky Mountain National Park, Colorado.

Recreation and its effects on trails in the Rocky Mountains have recently received attention. Marsh (1969) suggests that visitor use of Mountain National Park trails be regulated. He proposes planning and development for maximum user satisfaction and minimum environmental deterioration. A trail use survey in Banff and Yoho National Parks was carried out by Thorsell (1967). A proposal to develop a trail along the Great Divide produced several discussions. One by Thorsell (1968) discusses the location and need of such an extensive trail system. Root and Knapik (1972) examined trail conditions along a portion of the route and suggest improvements in trail location and maintenance. Carbyn (1969) warns that hasty development of the Great Divide trail will destroy wildlife habitats. The project must be taken in stages and thoroughly researched.

Peters (1972) examined hiking trails in Cypress Hills, Alberta, in terms of soil characteristics, vegetation and the amount of species across and alongside the trail. Vegetation increased in amount away from the centre of the trail, those species surviving on and at the trail edges being tolerant to rigorous trail conditions. Soil moisture

content, organic carbon content, acidity, and porosity increased linearly with distance from the centre of the trail while soil compaction decreased. The deepest trails in the Cypress Hills study were found on steep slopes where aspect and erosion by runoff are most prevalent. Peters' study is complementary to the present study in that it indicates the reaction of ground cover to trampling and the soil conditions under which certain species will survive.

Although information on trail use and degradation is scarce, a combination of literature from studies in conservation, soil science, ecology, recreation, and resource management provides sufficient material on which to base a trail study. However, this situation should be soon alleviated for trails in the Rocky Mountains with the publication of reports from the present government studies covering trail ecology and impact in recreation areas.

CHAPTER 2

STUDY AREA

2.1 LOCATION

The region chosen for study was the Folding Mountain area in the eastern Cordilleran region of west-central Alberta (Figure 3). A series of trails originates at the Circle M Ranch, which is located 320 km west of Edmonton, or 3.2 km east of Jasper National Park East Gate, and 0.8 km south of Highway 16. The ranch is situated at approximately 53°14' N and 117°47' W. Elevation at the ranchstead is 1170 m, and at the peak of Folding Mountain, 2117 m.

2.2 CLIMATE

Because of the study area's location within the eastern ranges of the Rocky Mountains, the winters are modified somewhat by maritime air masses and warm chinook winds blowing down the Athabasca River Valley. The precipitation and temperature regimes of the lower Athabasca Valley are represented by the Entrance (Figure 3) meteorological data for the period 1931-1960 (Figure 4). Great differences in slope, aspect, elevation, and exposure at points within this area combine with regional climatic conditions to produce microclimates for which no records are kept.

The large annual temperature range (Figure 4) shows the continentality of the climate. Summers are mild with July, the warmest month, having a mean temperature of 14.9° C. Winters are cold with an average January temperature of

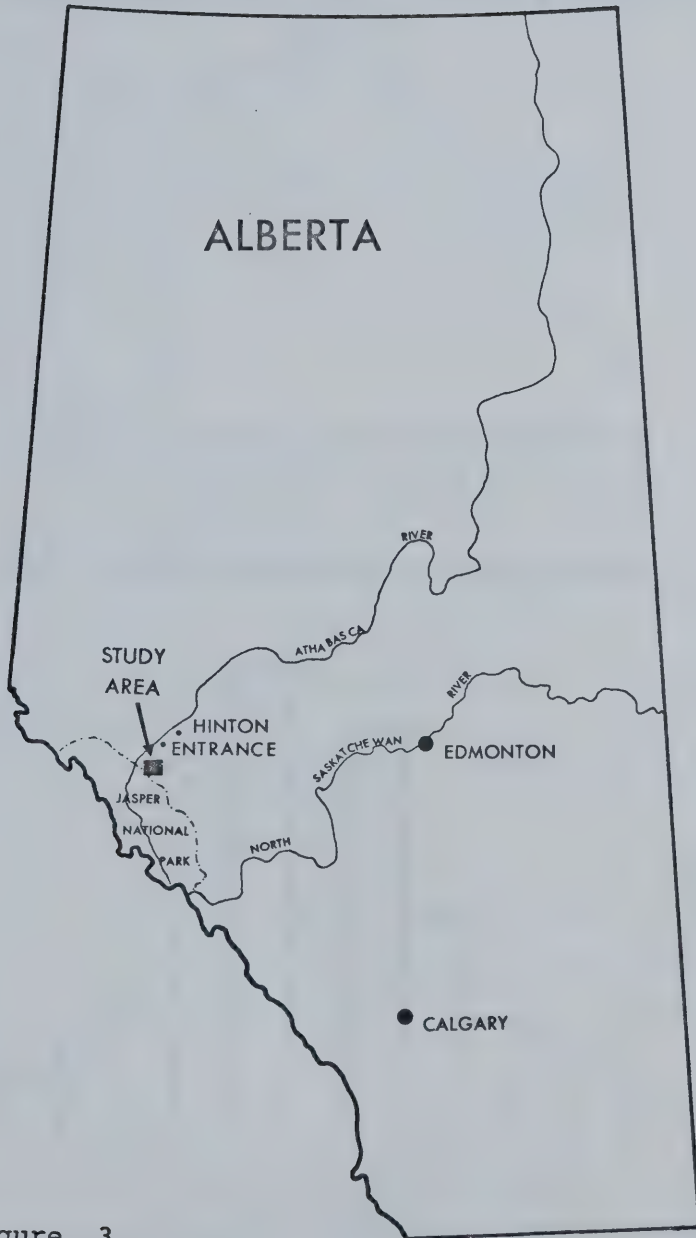
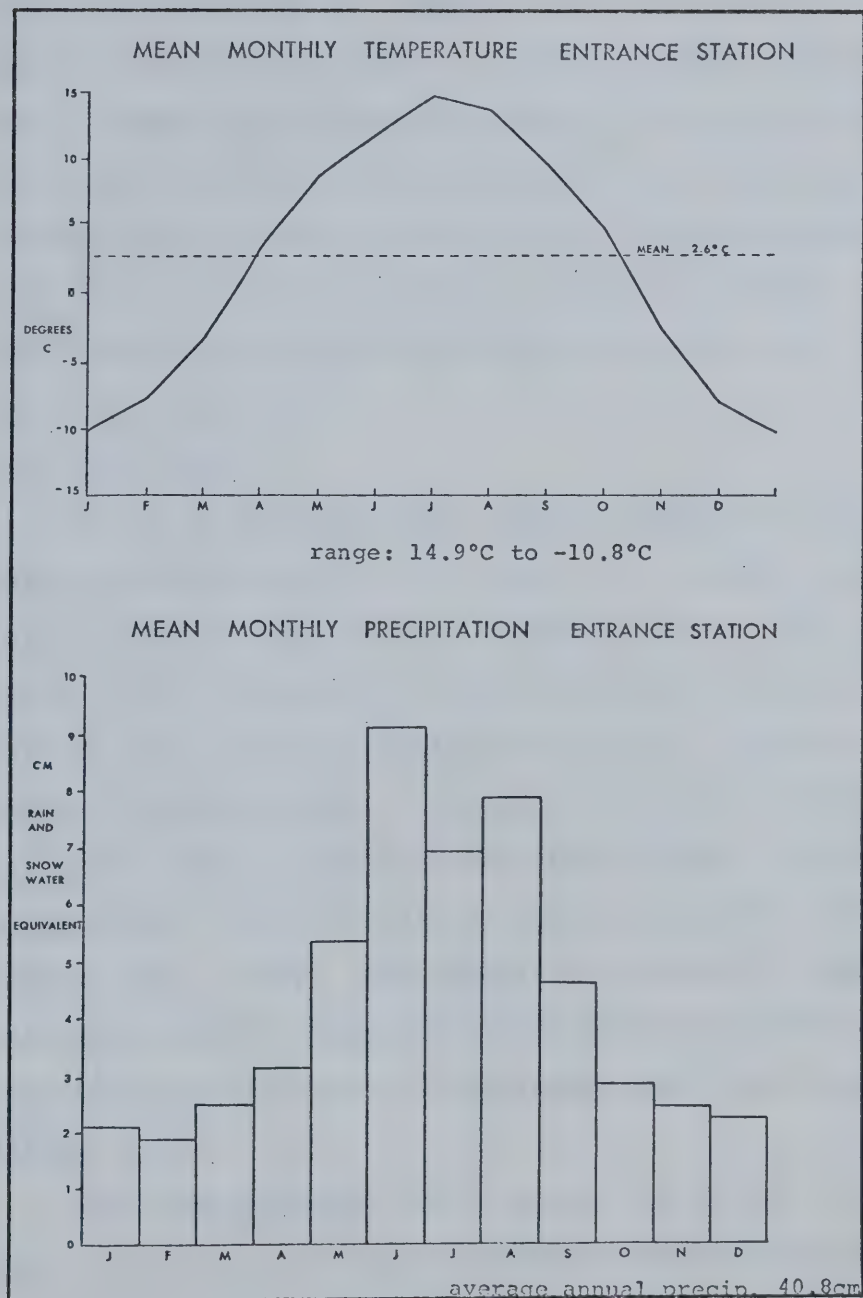


Figure 3



Source: Canada - D.O.T. Met.
Branch, 1967. Temperature
and Precipitation Tables
for Prairie Provinces,
3:6.

Figure 4

-10.8°C (D.O.T., 1967).

The average annual precipitation as measured at Entrance between 1931 and 1960 was 40.8 cm (rainfall plus snowfall water equivalent). A wide variation in monthly and yearly temperature and precipitation in the region may be due to the frequency and duration of moist air masses being lifted orographically, cyclonically, or convectionally from west of the Continental Divide, and the occurrence of polar continental air masses moving south along the east slopes of the Rocky Mountains.

2.3 PHYSIOGRAPHY

The Rocky Mountains and adjacent foothills were formed during the mid-Tertiary as a result of a period of uplift, folding and faulting of the Laramide Orogeny. The deformation in the foothills and Rocky Mountains increases from east to west as the foothills become more intensely folded toward the Front Ranges. The Rocky Mountain Foothills lie along the eastern margin of the Front Ranges in a narrow northwesterly trending belt of hills with folds and minor faults (Roed, 1968). The underlying bedrock is composed mainly of Mesozoic sandstones and shales with Paleozoic limestone and calcareous shale toward the Front Ranges (Irish, 1965).

The Rocky Mountain Front Ranges consist of a number of long, relatively narrow northwesterly trending sub-parallel ridges and valleys composed of a succession of overthrust sheets lying between southwesterly dipping faults. The study area lies at the interface of the Front Ranges and the

Foothills with the Folding Mountain anticlinal ridge (Foothills) to the east and Roche à Perdrix (Front Range) to the west.

Roed (1968) has identified the youngest sediment in the study area as Drystone Creek till. This till occurs in small valleys which emanate from cirques along the Front Ranges and Foothills and is recognized as a separate stratigraphic unit. A type locality for this till is along the east-facing cutbank of the Drystone Creek adjacent to the Circle M Ranch (NE 1/4 Sec. 18, T 49N, R 26, W, Alberta) where the till is at least 7.5 m thick and made up of pebbles derived mainly from local limestone. The till is brownish grey to medium grey with stones of diameters ranging from 2 cm up to 1.3 m. 74 percent of the gravels are limestone, the rest are composed of quartzite, sandstone, and siltstone. This calcareous silty clay matrix is texturally classified as clay loam with a high average carbonate content of 45 percent.

2.4 SOILS

There are no detailed surveys or maps of the soils in the study area. However, inferences can be made from the nature of the bedrock and the presence of Drystone Creek till in the region.

Because of the high limestone content of the bedrock (Rundle group of Paleozoic limestone and calcareous shale; Irish, 1965) most of the parent materials (or C horizons) are calcareous. Local exceptions exist because of varia-

bility in parent materials, topography, and climate, which results in a wide range of soil profiles. The National Soil Survey Committee of Canada (1963) stated that soils developed on till such as in this area belong to the Grey Wooded Great Soil Group. Brunisolic grey wooded soil has a loam texture and is found in the Alberta foothills over stony Cordilleran till (Alberta Soil Survey, 1967).

In the Athabasca River valley near Entrance and Hinton, the soils are developed on aeolian material that overlies till. The depth of the aeolian deposit is variable, ranging from a few cm up to one m. Morphologically, these soils fit the category of Brunizolic Grey Wooded Soils; however, chemical analysis (Roed, 1968) showed them to have a relatively high soil reaction (pH) and a high exchangeable calcium status. Such characteristics are not normally associated with Grey Wooded soils. The aeolian material is derived in part from the flood plain of the Athabasca River to the north and west. These flood plain deposits are high in calcium carbonate and this has an effect on the chemical characteristics of the aeolian soils.

2.5 VEGETATION

The lower sections of the study area lie within the Cordilleran Forest region. Dominant tree species on well-drained sites are lodgepole pine (Pinus contorta var. latifolia), white spruce (Picea glauca), and trembling aspen (Populus tremuloides), with balsam poplar (Populus balsam-

ifera) in poorly-drained areas, depressions, and seepage sites. Black spruce (Picea mariana) occurs sporadically in bog areas. Birch (Betula papyrifera), and shrubs of alder (Alnus ssp.), willow (Salix ssp.), and water birch (Betula occidentalis) also grow in the area, but in less abundance. Engleman spruce (Picea englemanni) appears at higher elevations and dense stands of alpine fir (Abies lasiocarpa) are dominant. Shrubs of bearberry (Arctostaphylos uva-ursi), buffalo berry (Shepherdia canadensis), and juniper shrubs (Juniperus communis and J. horizontalis) become increasingly abundant up-slope on the southwest-facing side of Folding Mountain, as do grasses (especially Agropyron ssp.).

Balsam poplar and aspen are abundant at lower elevations but decrease with an increase in elevation and a corresponding decrease in the aeolian soil deposits. This is also evident in the elevational variation from the spruce-aspen-grass association at lower elevations to the bearberry-buffalo berry-alpine fir association above 1370 m beyond the zone of the calcareous aeolian deposits.

Along timberline between 1675 and 1830 m is dense engleman spruce and alpine fir growth interspersed with rocky outcrops and open meadows. Low mats of willow, juniper, bearberry, and other hardy perennial shrubs appear just above timberline. Alpine tundra is found above 1850 m. The vegetation of this zone is composed primarily of perennial dwarf shrubs, mosses, and lichens.

2.6 REASONS FOR CHOOSING THE STUDY AREA,

The Folding Mountain area trails were chosen for study because of their montane and alpine characteristics as well as their aesthetic attractions. It is logistically practical to study a trail system just outside Jasper National Park, yet in the same geographic region, for several reasons. Transportation of equipment and accommodation difficulties were minimized by locating at one central place and taking short trips to observe trails in and near Jasper. The length of time the trails in the Folding Mountain area have been in use and the type and extent of use since their establishment is known. Although tallies of Park trail users are kept, the number of hikers and horses using the study area trails is much less and can easily be recorded since all use originates at the Circle M Ranch. Trails used exclusively by hikers, those used by horses, and those travelled by both are all accessible from the ranch.

The Folding Mountain trails receive less use than Park trails, thus soil has not been compacted beyond measurement, and the dynamic effects of hiking and riding can be more readily observed. Much travel would have been needed to observe trails of such varied use inside Jasper National Park. Furthermore, soil and plant sampling and removal is not permitted within the Park, and this was necessary in some cases for identification and laboratory work. Study plot markers were never removed by hikers on the Folding Mountain trails; this could not have been assured on the

intensively-used trails inside the Park. The study area trails receive the same type of use as those in the Park, and the season of most active use is the same.

2.7 HISTORY AND ESTABLISHMENT OF TRAILS IN THE AREA

The Athabasca River Valley and the east entrance to Jasper National Park are part of the main route through the Yellowhead Pass which was used by the Indians, explorers, and traders up until the early part of this century. The Yellowhead trail followed the south shore of the Athabasca River and kept to the high land along the north-facing slopes of Folding Mountain and Roche à Perdrix. The area was rich in game, so animal paths and hunters' trails extend south into the mountains from the main trail.

In 1940 Charles and Mona Matheson established the Circle M Ranch above the Drystone Creek and blazed a trail (Trail 4, Figure 5) over Folding Mountain. This and several other trails along the creek were cleared expressly for use by hunters and tourists. The main trail was blazed, but very little clearing was done. Portions of the trail followed existing game tracks. The southwest-facing slope of Folding Mountain does not have a heavy tree cover, so it was unnecessary to clear a path other than to remove dead-fall and eliminate some of the lower branches of the coniferous trees. Upon reaching timberline and alpine meadows at about 1675 m, the route simply follows the treeless ridge southeast to the peak of Folding Mountain. Loose

shale on the peak of the mountain is difficult to traverse, so Mr. Matheson cleared large slabs of shale and limestone to create a more stable track up the steep north face. This clearing has had to be kept up yearly, since rock slides, snow slides, and spring snow melt relocate soil and shale and sometimes obliterate the pathway. Once a trail was established and marked by tree blazes where necessary, the horses were kept to this path.

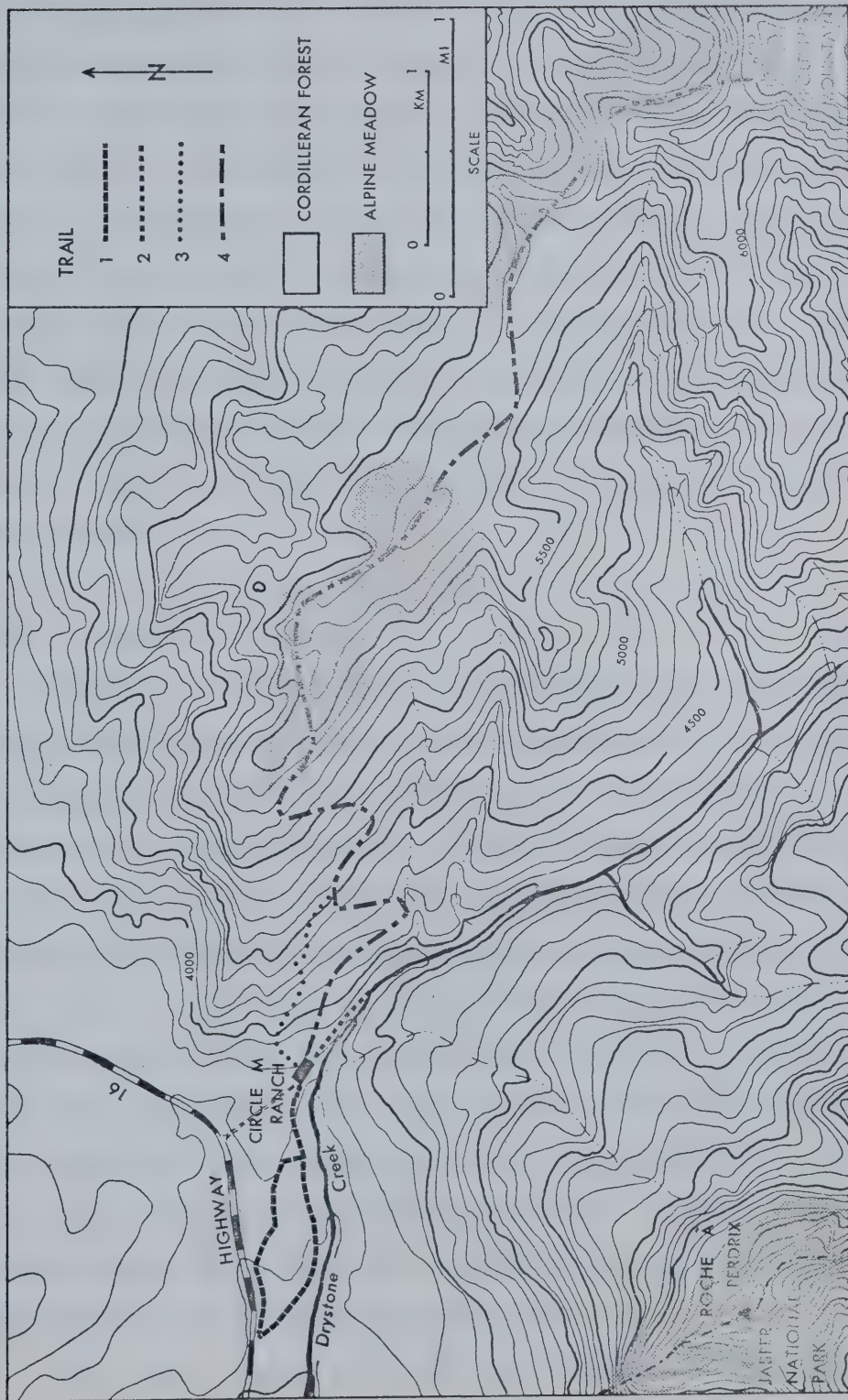
Trails at lower elevation developed in two ways; randomly by horses moving to pasture and by visitors and residents hiking around the ranch, and purposely for horse rides. One footpath to Drystone Creek has been maintained in that there are handrails and fixed stone steps on the steep sections. All other trails in the area are in an unimproved condition.

For thirteen years the trails were used regularly by the Matheson family and their guests until 1953 when the ranch property and horse grazing lease changed hands. Little work and use was received for ten years until 1963 when Mr. J. Redman purchased the ranch and resumed the use of the trails for riding and hiking. This use has continued for the past nine years and the trails are presently being used to a greater extent by the H.R. Cook family who utilize all the paths emanating from the ranchstead.

2.8 DESCRIPTION OF TRAILS IN THE FOLDING MOUNTAIN AREA

There are four major trails originating at the Circle M Ranch (Figure 5). Apart from some necessary as well as

FOLDING MOUNTAIN: TERRAIN, VEGETATION, AND TRAILS



CONTOUR INTERVAL 100 FEET (30.5 M) Source: Miette topo. sheets 83F, E and W.
Aerial photographs C69-11-CR626-L. 23-6,7.

Figure 5

accidental relocation in some places, the trails are essentially along the original routes. All trails receive a variety of impacts depending on whether they are used more for riding or for hiking. Although these trails are not used as intensively as those in Jasper National Park, it was considered reasonable to determine their conditions and seek comparisons with the Park trails. Conditions on the Folding Mountain trails were never such that it was impossible to conduct tests on soil moisture and compaction, or to describe the trail dimensions because of gross overuse or degradation.

2.8.1 TRAIL 1

Trail 1 (Figure 5) has been designated as an equestrian trail which extends from the north boundary of the Circle M ranchstead, and west along the bank of Drystone Creek. It crosses the creek and extends to the Jasper National Park boundary to the west, and branches to circle north toward Highway 16, around an abandoned gravel quarry, and back to the ranch. This route is popular as an easy hike, and either a one or two hour trail ride. Trail 1 is used more regularly than the other three trails in the Folding Mountain area and is most frequently used for short trail rides as it is scenic and conveniently circular. During the study season, this trail was travelled by about 50 hikers and over 500 horse trips on scheduled rides.

The area through which the trail passes is included in

the ranch grazing lease and is fenced. Thus, horses follow the trail when they are sent to pasture in the area, which adds an unknown amount of use. There is a variety of slope from 0° to 42° over which the trail passes. Trail 1 originates in a climax white spruce forest, passes along an exposed southwest-facing ridge colonized by juniper and bearberry, and swings north toward the highway into a predominantly trembling aspen, balsam poplar and grass zone. No vegetation was observed on the trail itself.

2.8.2 TRAIL 2

Trail 2 (Figure 5) is a pedestrian footpath which extends from the ranchstead south along an exposed southwest-facing ridge, through white spruce stands, and down a steep slope to the Drystone Creek at about 1060 m where it disappears onto sand and gravel bars. Horses may occasionally stray onto this trail, but it is mainly used by pedestrians. The steeper sections of Trail 2 where the slope exceeds 35 or 40° are lain with stone steps and bordered by wooden handrails. Many tree roots are exposed on the trail, but are not split and free-standing as they are on horse trails.

This trail is short, about 250 m, and is therefore very popular with casual walkers. Besides, it is the only route to the creek other than cross-country. The soil is a sandy loam with patches of gravel. In descending order of significance, vegetation along the trail includes white spruce, trembling aspen, bearberry, juniper, wild rose,

(Rosa acicularis), buffalo berry, and saskatoon bushes (Amelanchier alnifolia). At no point is there vegetation on the pathway.

2.8.3 TRAIL 3

Trail 3 (Figure 5) is used strictly by unriden horses on their way to and from pasture on Folding Mountain. This trail joins the main trail (Trail 4) about 500 m up-trail from the ranchstead and is located entirely within a white spruce forest. At lower elevations the trail is wide and the soil has a very high moisture content in spring and early summer because of the abundant springs issuing from the base of Folding Mountain. Uphill, however, Trail 3 is not affected by spring water; it levels out, and becomes extremely narrow reaching only 0.4 m in width in some places. Varied slope is encountered on this trail and incision increases markedly with slope over short distances.

2.8.4 TRAIL 4

Trail 4 (Figure 5) is the main route from the Circle M ranch to the peak of Folding Mountain. This trail begins with a very steep ascent to the 1675 m ridge that runs southeast to Folding Mountain. The vegetation at lower elevations and below this ridge includes thick stands of white spruce and lodgepole pine. Bearberry and juniper are abundant on exposed and steep slopes, and clones of trembling aspen are prominent at about 1215 m. Topsoil up to this elevation is 0.5 m deep in places. Above 1215 m, the

trail follows somewhat exposed and progressively more rocky southwest-facing ridges. Soils on these sites are dry and have crumbly structures. Exposed ridges are interspersed by treed hollows until about 1600 m where timberline is encountered. The trail here is steep and covered with loose limestone and sandstone slabs. At 1675 m the trail levels onto alpine meadow and passes through patches of stunted subalpine fir and low water birch. The trail becomes less evident on the meadow as the path is less restricted by trees and slopes. From the meadow, the trail ascends the steep loose shale peak of Folding Mountain. There is no vegetation on the pathway until the alpine meadow is reached; here there are frequent grasses and occasional cushion plants surviving on the path. At places along the trail steps have been formed over tree roots or stones. This is most evident on slopes where the soil on the down-trail side of the obstacle has been removed by running water and mass movement.

Because of the constant slope of Trail 4, horses and hikers alike frequently stop to rest. Some rest stops have been established in areas relatively clear of trees and ground vegetation. At these rest stops it is the nature of both horses and hikers to break single file and bunch together several abreast or stroll about at right angles to the trail. Where this has occurred the trail is up to 3 m in width and the track is much shallower than that of the confined trail. At these sites, the ground vegetation is

sparse and lower branches have been broken from trees. This results from horses being tethered, and from grazing and trampling, and also from hikers clearing spaces on which to sit or place their packs.

Trail 4 is followed by all traffic going to Folding Mountain. Equestrian use here is much greater than pedestrian use, but the trail is followed at least as far as the alpine meadow by a significant number of hikers each season. This trail was considered equestrian but some effects of pedestrian use were observed.

Meaningful measurements of trail depth and soil compaction were impossible to secure above the alpine meadow where the trail ascends to 2135 m. The topsoil is rarely more than 4 cm in thickness and the trail is mainly covered by limestone slabs and talus.

2.9 DESCRIPTION OF ASTORIA RIVER-TONQUIN VALLEY TRAIL

This trail was observed in order to determine whether the impacts of use on the Folding Mountain trails were similar to those of hiking and riding trails in Jasper National Park. The trail lay-out and management recommendations made in this study are meant to apply to trails both inside and outside the Park bounds.

The Astoria River-Tonquin Valley Trail (Figure 6) follows a scenic mountain pass from Mount Edith Cavell to the Amethyst Lakes about 24 km by air southwest of Jasper townsite. This is the most popular and most heavily used trail in the Park. It receives thousands of hiking and

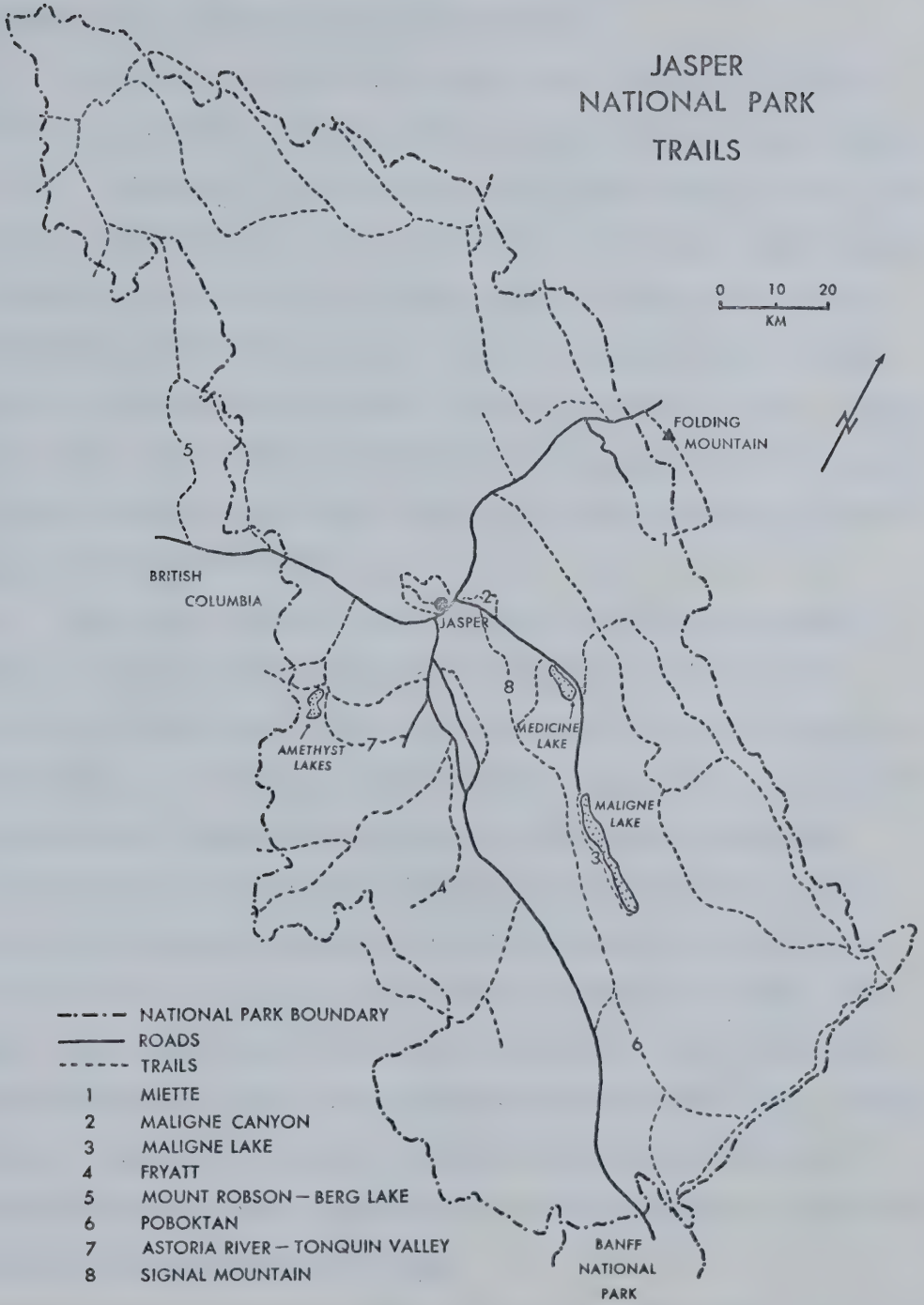


Figure 6

riding visitors each year as compared to only several hundred on the Folding Mountain trails.

In 1970 the number of hikers and overnight campers along the Astoria-Tonquin Trail was more than twice that in 1969¹. Because of this recent increased visitor use of the trail, the biological and aesthetic values are depreciating. Overuse and misuse can quickly turn the area into an unpleasant and recreationally inferior countryside. Damage to the Astoria-Tonquin Trail occurs in various forms since the trail goes through subalpine forest, alpine tundra and meadow, along river banks, and over sedge meadows surrounding the Amethyst Lakes.

This trail begins just outside the "Intensive Use" area of Mount Edith Cavell as designated in the Jasper National Park Provisional Master Plan (1970). The trail is situated in a "Natural Environment" area; that is, a transition zone between heavily-used or developed areas and wilderness back country. Despite this designation, the trail to Amethyst Lakes is receiving excessive and uncontrolled use. Vegetation has been devastated at camp sites, the trail has been widened by both hikers and horses, and parallel trails have been developed especially above timberline. The large numbers of hikers and horses along the Astoria-Tonquin trail detract from the wilderness characteristics and appeal of the area.

1. Personal Communication: B. Armstrong, Head Warden, Jasper National Park, July, 1972.

CHAPTER 3

RESEARCH METHODS

3.1 INTRODUCTION

Measurements were taken on all five trails to determine the effects and extents of different types of use on the same slope and the effects of the same use on various slopes. Use of each trail was considered uniform along the entire trail, or that portion of the trail observed. On Trail 4 it was assumed that use was uniform along its length; that is, from the montane forest through timberline to and along the alpine meadow. It is known that pasturing horses usually follow the trail to the open meadow at the top of the 1675 m ridge and that any equestrian trips originating at the Circle M Ranch follow the trail in its entirety to the peak of Folding Mountain. Hiking use as observed was for the purpose of viewing the alpine meadow or ascending the mountain peak. Therefore, the trail was followed to the top of the ridge and beyond to at least 1.5 km south-southeast along the meadow.

3.2 LOCATION OF STUDY PLOTS

Sample sites were selected on the Folding Mountain trails and on specific walking and riding trails in Jasper National Park. Sites on Folding Mountain were situated on four trails or sections of trail depending upon:

1. type of use,
2. amount of use, and
3. degree of slope.

Each study plot is distinctive in type and extent of use and over the four trails there is a range of vegetation from grass through stands of white spruce and trembling aspen to alpine meadow and fellfield. The plots provide varied slope from 0° to 43°. A variety of drainage is present in this trail sampling from poorly-drained seepage hollows to well-drained sand and gravel slopes.

The four Folding Mountain trails and the Astoria-Tonquin trail are described in the preceding chapter. Their characteristics are summarized as follows:

- Trail 1 - intensively used as a horse trail both
 - for rides and by horses in pasture
 - few hikers
 - predominantly level with some slope differences
 - spruce and poplar, clearings artificial, some exposed sections with southwest aspect supporting juniper and bearberry
- Trail 2 - solely and intensively used by hikers
 - variety of slope from level to very steep
 - some southwest exposure mainly supporting white spruce and bearberry
- Trail 3 - exclusive and intensive horse use
 - variety of slope
 - trail begins in willow thickets along springs and extends into mature white

spruce stands

- Trail 4 - equestrian use less intense than on Trails 1 or 3
- moderate pedestrian traffic
 - variety of slope, soil, and drainage characteristics
 - variety of vegetation from white spruce-poplar associations to alpine meadow reaching bare rock and scree slopes at high elevation

Astoria-Tonquin Trail:

- frequently travelled by pack trains and wardens on horseback
- continuous heavy hiker use
- slope varies from 2° to 16°, steep sections being reduced by switch-backs
- trail begins in lodgepole pine and white spruce forest and reaches alpine meadow and sedge flats

3.3 TRANSECTS AND MICROTOPOGRAPHY

Transects were established following a stratified sampling pattern to best represent use and slope variations. Level and sloping portions of each trail were measured in cross-section to determine differences in the erodibility of the inclined trail.

A transect 3 m long was established perpendicular to the trail at each test site with the centre of the transect at mid-trail. Measurements of trail depth, width, slope, and soil compaction were taken on each cross section. Control points were established in the ground at both ends of the transect and the measuring tape secured at a point 2 cm from the ground surface on control pegs.

3.4 TRAIL DEPTH

Depth of the trail was measured from the permanent 2 cm level established between the control points at 15 cm intervals using a plumb-line. These readings, along with slope of the hill-side are used to plot transect microtopography graphs onto which soil compaction readings are also displayed. Depth readings illustrate the effects of horses and hikers in altering trail dimensions as well as the increase of incision with increasing slope (particularly on horse trails).

3.5 SLOPE

Hill and trail slopes were measured using an Abney level and 2 m staff. Hill slope is given as the unmodified hillside near the path while trail slope is measured along the path. Trail slope is indicated alongside each depth and compaction graph in the following chapter.

3.6 SOIL COMPACTION MEASUREMENT AND EQUIPMENT

Static penetration tests were made at all sample sites on the trails studied. This test employs a soil penetrometer pushed steadily into the soil and measures the soil resistance to vertical penetration. Measurements to determine compaction or hardness caused by pedestrian and equestrian use of trails were taken with pocket and cone penetrometers.

Compaction readings were taken at 15 cm intervals across each transect. Preliminary work was carried out with a pocket penetrometer, and subsequent readings with a cone penetrometer. Three readings were taken at each interval. These were well-spaced in order not to affect the others and were placed perpendicular to the transect along the trail. An average was taken of the three to give a compaction reading at each interval. In order for relative uniformity of soil conditions, all compaction readings were taken 3 - 4 days after rainfall. Field season conditions were such that rainfall was relatively frequent and consistent throughout the testing period.

From a theoretical point of view, the mechanics of soil penetration tests are not well understood. Direct interpretation of the results in terms of the strength of the soil is not possible. Therefore, soil compaction tests must be considered empirical (Freitag, 1971).

3.6.1 POCKET PENETROMETER

This apparatus is hand-operated and works on a spring balance which shows the unconfined compressive strength of the soil in kg/cm^2 or T/ft^2 on a calibrated scale. The pocket penetrometer is accurate only to $\pm 20\%$ (Davidson, 1965). However, the compaction readings taken with this instrument were adequate, especially during field reconnaissance and preliminary testing before setting up the premise that horse and hiker use of trails had different comparative results. Soil compaction measurements were comparable to those taken at the same sites under similar field conditions using a more reliable cone penetrometer.

3.6.2 CONE PENETROMETER

The Soiltest cone penetrometer is an apparatus used for the measurement of compaction of trafficability of fine-grained soils. This is interpreted as a function of soil strength which, in turn is calculated from the measurement of force in kg required to press the penetrometer into the soil. The cone penetrometer consists of a handle, proving ring, dial gauge, a 1 m graduated rod, and a steel cone 4 cm in height.

Chancellor (1971) discusses soil compaction and testing with a cone penetrometer and states that since the interpretation of readings in terms of other soil parameters is a problem yet to be solved, only comparative measurement of soil strength can be made. Chorley (1959) used the cone

penetrometer to find the variation of resistance to sheet erosion between samples of a single geological soil group. Chorley pointed out that error enters into penetrometer readings if the instrument is not pushed into the soil steadily, if all readings are not taken by one operator, and if gravel in the soil is encountered and increases the pressure reading.

Cone penetrometer readings are taken at 15 to 30 cm depths on soils travelled by heavy vehicles. This is considered the critical layer where the cone index is a measure of trafficability of soils supporting heavy military vehicles (Davidson, 1965). Readings on hiking and horse trails were taken at 4 cm, or to the top of the steel cone. Upon testing, it was found difficult or impossible to insert the penetrometer to any greater depth especially on well-travelled pedestrian paths.

3.7 SITE DESCRIPTION

Observations were made of the vegetation and soil characteristics at each site. Erosion and drainage patterns and peculiarities such as natural steps on the trail, short cuts, and wild animal trail use were noted. The habits and effects of horses and hikers walking and resting were observed as were effects of horses browsing and grazing at specific sites and along the trails.

CHAPTER 4

RESEARCH RESULTS

Results of observation and measurement of hiking and riding trails are described qualitatively and quantitatively for each trail. Their characteristics and dimensions are detailed in conjunction with the type and extent of use the trail received. Many degradation patterns were found to be similar on all trails, but differences occurred where the incline or use varied.

4.1 TRAIL 1

This relatively level trail used mainly by horse traffic has undergone only slight damage at places where the slope is inclined. Maximum trail depth was recorded as 54 cm at a site with a slope of 22° . The average maximum compaction on a site cross section was 42.3 kg, and the minimum 21.0 kg. This trail is well located in that it follows a dry south-facing ridge and descends onto the gravel bars of the Drystone Creek. The trail is narrow because of the single file nature of trail riding on horseback. The trail cuts directly downslope in several places, and it is here that the maximum downcutting has occurred. Elsewhere, the trail is not incised severely, nor have the trail sides been eroded to cause excessive widening of the path. Although the trail receives much horse travel, since it is relatively level, soil compaction is high thus reducing soil erosion and movement downslope.

During spring melt, some sections of this trail were covered with snow and were muddy and slippery. (Plate 1). Horse traffic by-passed these sections and caused some trampling damage along the trail sides (Plate 2).

4.2 TRAIL 2

Trail, 2, mainly used by pedestrians, is wide, shallow, and the soil is densely compacted in relation to equestrian trails. Trail depth varied from 12.5 cm to 31.0 cm. The minimum and maximum soil compaction readings across the trail were 38.2 kg and 51.5 kg. These readings were much higher than those on Trail 1. The upper section of Trail 2 is well located on a level stream terrace with a southwest exposure. Toward Drystone Creek the trail is extremely steep and supported by stepping stones and a guard rail. No extreme damage was noted on the lower sections of this trail where the path follows sand and gravel bars.

4.3 TRAIL 3

Damage to Trail 3 is excessive because of continuous horse traffic, steepness, shade¹, and running water from springs in the area. The trail is incised between 23 cm and 42 cm and slopes to 30°. The soil is soft and movable

1. Thick spruce stands block sunlight from the trail thus reducing evaporation from the soil. Wet soil on a trail is more susceptible to compaction, mass movement, and relocation than firm, dry soil.



Plate 1 Snow patches on Trail 1 soften trail and erode soil during runoff. Muddy patches are avoided by horses and hikers and trail width is increased. May, 1972.



Plate 2 Horses avoiding snow and mud on Trail 1 have trampled and damaged trail-side soil and vegetation. May, 1972.

with minimum and maximum compaction readings of 21.6 kg and 33.3 kg. Since the trail is used exclusively by horses without any control it follows a steep slope for about 50 m just beyond a very marshy low area to the northeast of the ranchstead. This site is in a shaded willow thicket where the trail measures up to 1.8 m in width. Once Trail 3 reaches a dry, level ridge it narrows to 0.5 m and decreases in depth in several cm.

4.4 TRAIL 4

The main trail from the base to the peak of Folding Mountain is heavily used by horses and seldom by hikers. On the southwest-facing slope of the mountain, the trail becomes steep in some sections with a resultant incision of up to 65 cm. Steps have been formed over tree roots and boulders in the trail, and the path has been widened considerably at rest stops. Since this trail is travelled by horses carrying pack boxes, trail-side trees have been stripped of their branches up to about 1.3 m. No significant damage to vegetation by grazing or browsing was observed.

Because of the steepness of the slope of Folding Mountain at lower elevations, shortcuts have been incised straight down-slope by both hikers and horses. Many shortcuts have been made around steep or wet sections of trail (Plate 3).

Once the trail leaves the treed slope and levels out



Plate 3 During wet conditions, original trail on left was abandoned by horses and new trail formed on right. Photograph taken one week after new trail was begun. Note absence of vegetation on original trail and sharp demarcation of trail sides. Trail 4. July, 1972.

onto alpine meadow at 1675 m and above, it is narrow, shallow, and in good condition (Plate 4). The trail has not spread out or cut across the meadow ridges. Trail-side vegetation is grazed by horses, but not irreparably. Toward and on the peak of Folding Mountain the trail is maintained on rock steps and limestone scree and is difficult to traverse especially on steep sections (Plate 5, 6). At high elevation, 3125 m, traces of traffic on alpine soil and vegetation are almost indistinguishable.

As on the aforementioned three Folding Mountain trails, there are no signs of litter or destructive behaviour on Trail 4.

4.5 ASTORIA RIVER - TONQUIN VALLEY TRAIL

Contrasting with the Folding Mountain trails, the Astoria River - Tonquin Valley trail system receives excessive hiker and horse use during the summer season. Overuse and misuse have caused irreparable damage to long sections of this trail. Trail width was found to exceed 6 m in places and soil compaction reached 110 kg and over (Plate 7). Up to six paths have been worn parallel to one another because of hikers' distaste of following horse trails (Plate 8). Wet patches of trail have been widened by trampling on verges¹ which subsequently eroded and fell onto the

1. It was found that a definite edge or bank existed alongside all trails. In order to avoid a wet trail, hikers and horses took to the higher, vegetated, and firmer bank or verge.



Plate 4 Trail 4, Folding Mountain, in good condition on alpine meadow at 1740 m elevation. July, 1972.

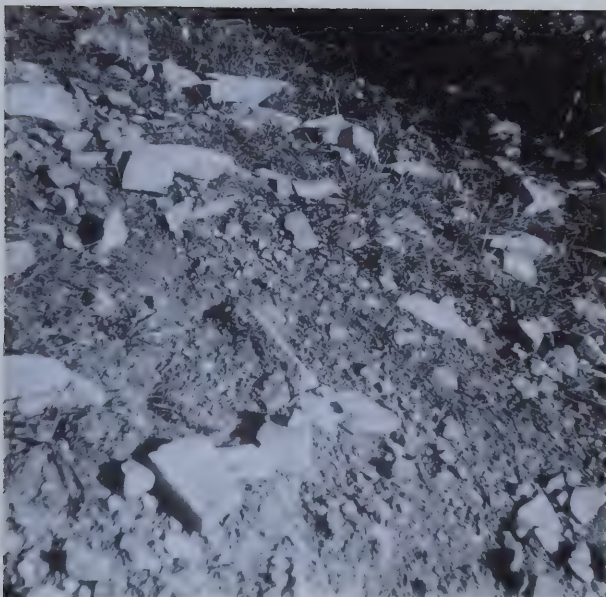


Plate 5 At break of slope where Trail 4 levels onto alpine meadow the trail is difficult to traverse because of limestone slabs and unstable slope. July, 1972.



Plate 6 Trail 4 ascends the steep, rocky, west-facing peak of Folding Mountain. Rock avalanche lines can be seen at mid-slope. July, 1972.



Plate 7 Switchbacks on Astoria River - Tonquin Valley Trail (Trail 5) are wide and severely compacted. This trail has been levelled and gravelled in places. August, 1972.



Plate 8 Severe damage has resulted from horse traffic along Trail 5 - especially on wet sections. Note hiker path on right avoiding churned horse trail. August, 1972.

path. Trail planking and bridges have been only partially successful in restricting traffic to the trail. Rest stops and campsites have been excessively trampled, vegetation has been killed, and litter has been strewn all along the 22 km trail to Macarib Creek.

4.6 TRAIL SLOPE AND DEPTH

It was observed that with an increase in trail slope, there was a corresponding increase in trail depth. This was most prevalent on trails used solely or predominantly by horse traffic. As a result of the loosening of soil by horses' hooves, there was an increase in soil erosion by runoff and minor creep. The extent of this erosion was determined by the degree of trail slope. Trails, or portions of trails, principally used by hikers were more subject to dense soil compaction than to incision. However, once the vegetation cover was trampled and removed, an increase in trail depth did occur on hiking trails. This hypothesis that a horse trail increases in depth with an increase in slope was shown to be correct in the statistical analysis. The trails heavily used by horses scored significant correlations in comparing trail slope to maximum trail depth. Correlation coefficients were derived from computer output. The T-test for significance was used to obtain confidence levels.

Table 2 Correlation coefficients between trail depth and trail slope

Trail	n	Correlation coefficient depth to slope	T-test figure	Significance level
1	9	0.939	7.23	99%
3	4	0.839	2.18	85%
4	9	0.835	4.01	99%

The two trails used mainly by pedestrians, Trails 2 and 5, had respective correlation coefficients of 0.504 ($n = 6$, $T = 1.17$, sig. level = 70%) and 0.503 ($n = 8$, $T = 1.43$, sig. level = 80%). The correlation for depth and slope for all trails was 0.759 ($n = 36$, $T = 6.81$, sig. level = 99%) which shows a significant relationship.

The maximum and mean trail depths correspond with the type of use received by the individual trails:

Table 3 Trail Depth

Trail	n	Maximum depth	mean depth	type of use
1	48	54 cm	23 cm	riding
2	42	31 cm	16 cm	hiking
3	20	42 cm	26 cm	riding
4	53	65 cm	28 cm	riding
5	75	31 cm	16 cm	hiking

Maximum and mean trail depth was found to be lower on the two trails which received more pedestrian than equestrian traffic. It was found, however, that on level and alpine trails the depth of incision was similar for both types of use. This was credited to the lack of soil erosion both by mass movement and running water down-slope and the

increased surety of footing thus reducing slippage and movement of soil especially by hooves.

The increase in trail depth with an increase in slope can be shown graphically using microtopographical cross-sections of two sites on Trail 1. These sites were in the same vegetation zone and received equal amounts of use by horse traffic. The slope at Site 6 was 1° , and, at Site 9, 22° . The mean trail depth for Site 6 was 7.5 cm and the maximum was 16.0 cm. The mean depth at Site 9 was 19.1 cm and the maximum was 54.0 cm (Figure 7).

Trail incision lessens with an increase in elevation where the soil layer became thin or totally absent. Above 1675 m soil compaction measurements are virtually meaningless because of the high stone content of the soil which inhibits accurate measurement taking.

4.7 TRAIL WIDTH

Trails widen in relation to the surrounding vegetation, the terrain, and the type of use. Paths through trees range from 0.5-0.8 m in width because of restriction by trees and logs.

Minimum trail widths are similar for horse hiker trails. Increased width of hiker trails is shown in the maximum and mean trail width figures:

EFFECTS OF HORSE USE ON TRAIL DEPTH AT SITES OF DIFFERENT SLOPE

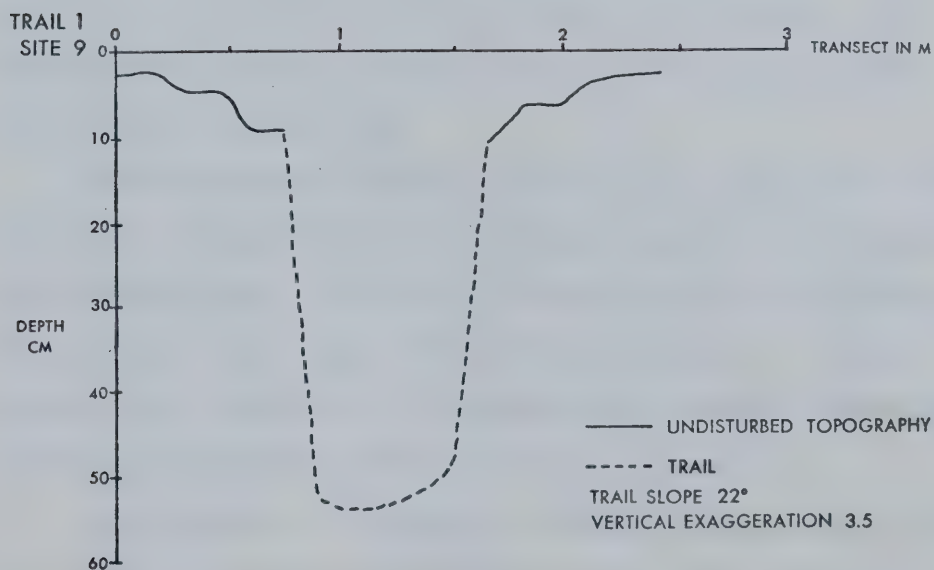
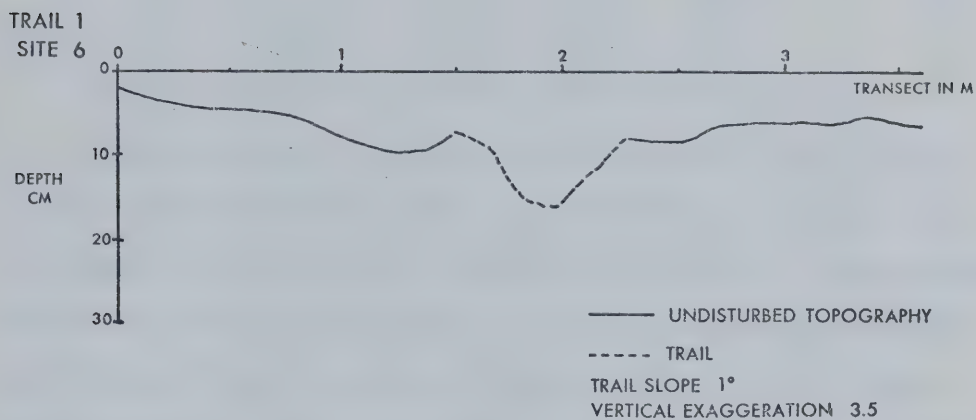


Figure 7

Table 4 Trail Width

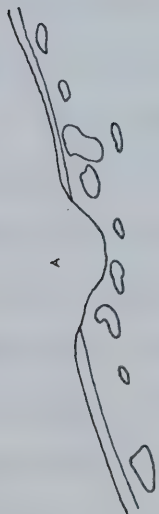
Trail	n	Minimum width	Maximum width	Mean width	Type of use
1	9	0.58 m	1.20 m	0.70 m	riding
2	6	0.50 m	1.30 m	1.00 m	hiking
3	4	0.61 m	0.61 m	0.61 m	riding
4	9	0.50 m	1.00 m	0.78 m	riding
5	8	0.61 m	3.10 m	1.40 m	hiking

Travellers are less able to venture off the track at lower elevations than above the timberline. However, where the timber is less dense, widening does occur. The trodden width of the trail increases to 6 m in places where horses and hikers stop to rest on Trail 4. After a rain when a path is muddy, the trail sides are used both by hikers and horses to avoid wet or slippery sections. This occurs most often with hikers who refrain from using a muddy horse track and walk along the more compact trail edges. The verge soon gives way, falls onto the trail, and becomes part of the used pathway.

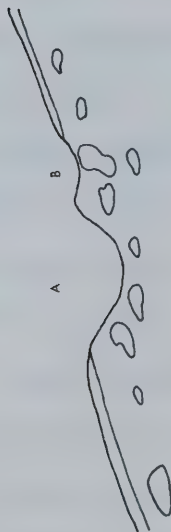
In some places along Trails 4 and 5 a subsequent trail developed upslope from the original because of unfavourable trail conditions. Because of a steep trail or hillside, the uphill trail loosens the intervening soil, a slump occurs, and results in a very wide trail made up of unconsolidated boulders, gravel, and soil (Figure 8).

The effects of distaste for soiling one's feet, and the desire to trod on vegetation rather than soil, were observed on all trails including several wilderness and

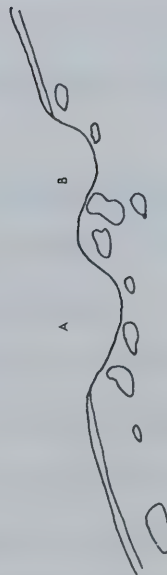
STAGES OF TRAIL EROSION



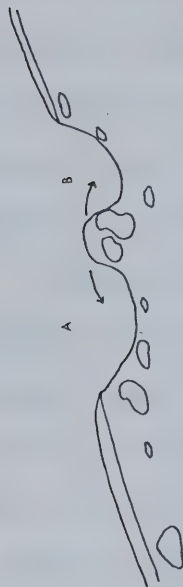
Original Trail A



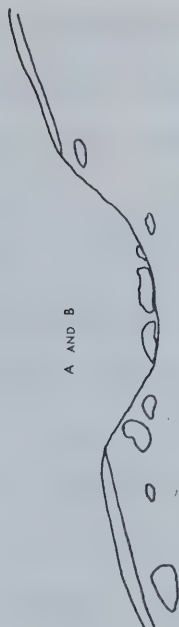
Trail A eroded by running water. Rock, mud, or exposed roots on trail make walking or riding difficult. Trail B begun up-slope parallel to original trail.



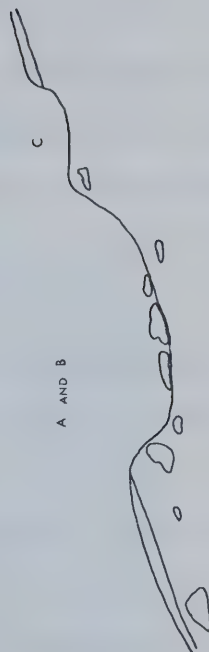
Trail B continues to erode.



Trail B further erodes and undercuts division between paths.



Boulders and loose earth make travel on subsequent trail difficult, especially if trail is wet or steep.



Trails A and B abandoned and Trail C begun parallel to old track.

Figure 8

nature trails in Jasper National Park. The maximum trail width recorded along the Astoria-Tonquin Trail was 3.4 m. In places several trails were found alongside each other, and these were obviously used alternately by hikers and horses. Many hiking parties were observed walking 3 or 4 abreast, as were horses.

Intensively used pedestrian trails were observed at Maligne Canyon, Miette Hot Springs, Mount Edith Cavell, Maligne Lake (Figure 6), and many scenic viewpoints in Jasper and Banff Parks. These trails had only been incised a few cm, but were all completely devoid of vegetation and extended up to 8 m in width. The trail to Berg Lake in Mount Robson Provincial Park, B.C. (Figure 6), was observed during rainy weather. Traffic had widened and damaged soft sections of the trail to the extent that they were impassible in places (Plate 9). No visitor-number records are kept at these sites, but it is estimated that thousands of tourists visit these attractions or viewpoints between June and September every year.

Trail width on alpine meadows usually does not increase to an undesirable extent. Instead, several trails are usually formed as shortcuts across open meadow. Because of the elevation and the usually level nature of meadows, there is a thin soil layer and the trail is fairly flat. Therefore, there is little cause for soil erosion or trail deepening. However, alpine trails do display the effects of use for greater lengths of time than do sub-alpine or



Plate 9 Berg Lake trail in poor condition. Excessive use has turned sections of this trail into a wide quagmire. July, 1972.

forest trails because of the time needed for trampled plants and shrubs to recover and subsequently revegetate the trail.

Above the elevation of trees and shrubs, trails follow rock ridges, scree slopes, and rock steps. Very little damage or degradation takes place other than some relocation of rock slabs, boulders, or gravel. Any damaging effects along high-elevation trails result from the strewing of litter, the painting of rocks or peaks, and the dislodging of sufficient rock material to cause rock slides.

4.8 SOIL COMPACTION

Soil compaction on trails varies mainly with slope, type of use, and amount of use. On dry, level trails in any vegetation zone, hiker and horse trampling produce similar compact soil conditions.

On horse trails changes in compaction occur with a change of soil moisture, i.e. the presence of streams or springs; and a change of slope. Figure 9 shows in cross-section that level sites suffer some down-cutting and considerable compaction while steep sites are severely incised and compaction is low.

Hiking trails are seldom incised as deeply as horse trails at the same slope, but display excessive compaction. Figure 10 shows cross-sections of a horse path and a foot-path on sections of the main Astoria-Tonquin Trail. Although the slope is similar at both sites, the hiking trail is more compact.

EFFECTS OF HORSE TRAMPLING ON TRAILS OF DIFFERENT SLOPE

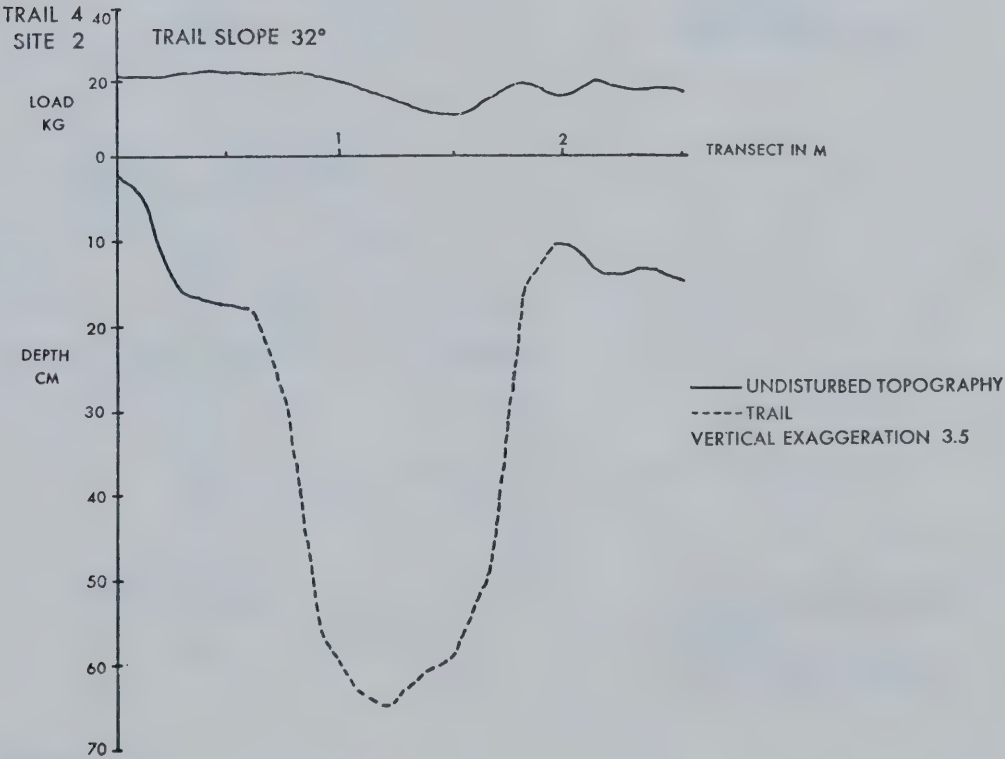
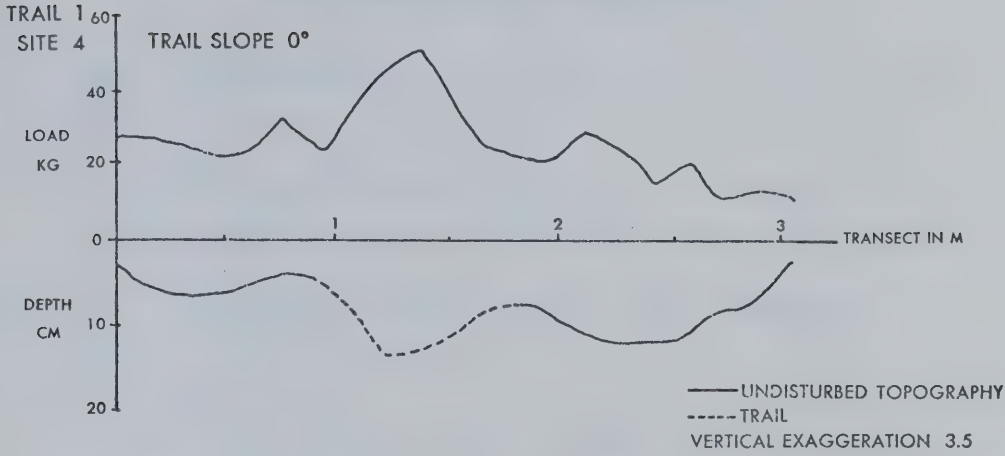


Figure 9

EFFECTS OF TRAMPLING ON HORSE PATH AND FOOTPATH OF SIMILAR SLOPE

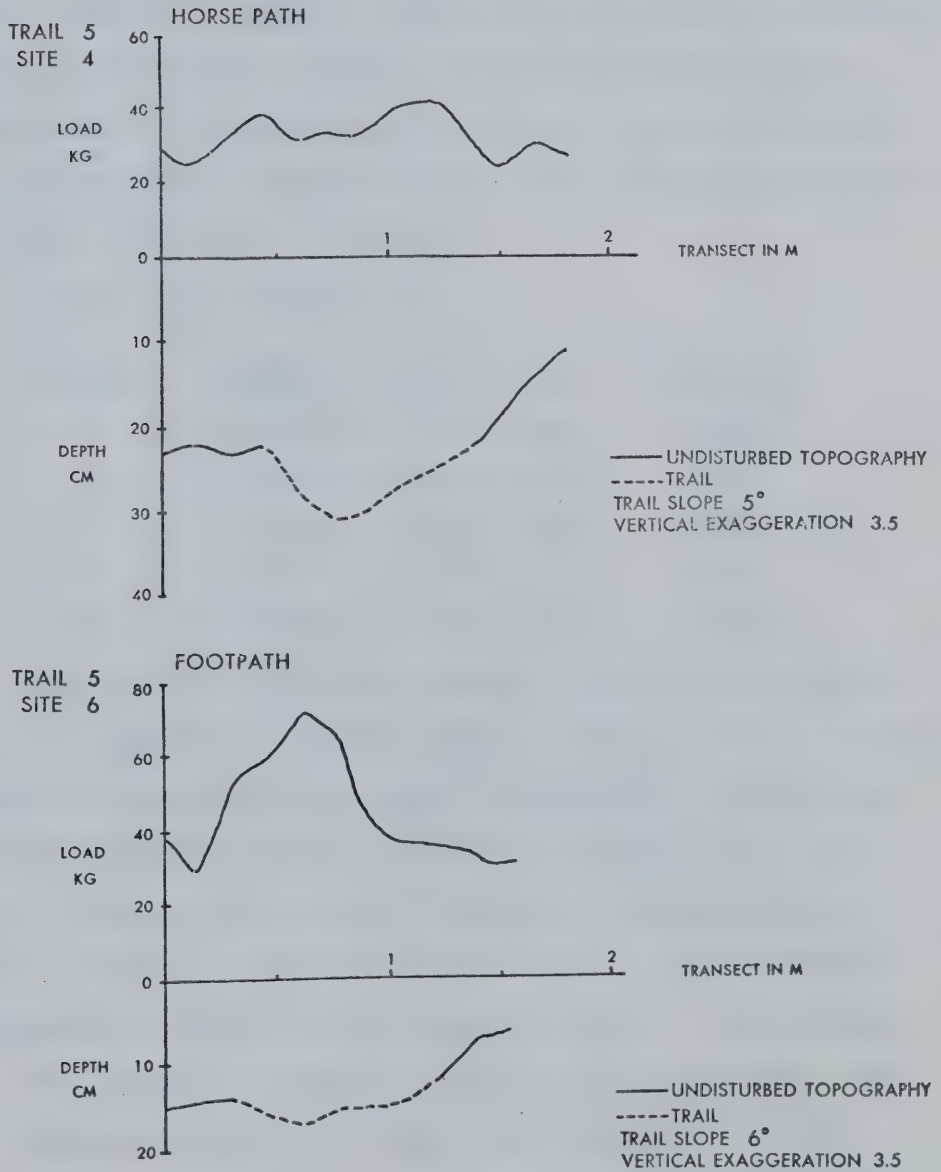


Figure 10

Excessive soil compaction was recorded on the intensively-used Astoria-Tonquin Trail which is considered predominantly a hiking trail (Figure 11).

It was not possible to determine the compaction of trails leading to popular scenic viewpoints such as Maligne Canyon and Miette Hot Springs due to the extreme density of the soil which prevented insertion of the penetrometer.

The maximum, minimum and mean soil compaction readings for each trail were as follows:

Table 5 Soil Compaction

Trail	n	Maximum compaction	Minimum	Mean	Type of use
1	48	55.3 kg	11.8 kg	30.6 kg	riding
2	42	70.8 kg	19.1 kg	43.9 kg	hiking
3	20	47.6 kg	9.5 kg	29.2 kg	riding
4	53	37.2 kg	9.5 kg	22.7 kg	riding
5	75	109.7 kg	14.1 kg	55.0 kg	hiking

Hiking trails show much higher minimum, maximum, and mean soil compaction readings than do riding trails. An increase in hiking use also shows a significant increase in readings of compaction from Trail 2 to Trail 5 (Astoria-Tonquin Trail). Riding trail compaction was recorded as higher on Trail 1 than on Trails 3 and 4. This could be a consequence of the level nature of Trail 1 - mean slope 10°. The steeper the slope, the less the compaction. The mean slopes of sites on Trails 3 and 4 were 16° and 22° respectively with Trail 4 having the lowest soil compaction readings.

SOIL COMPACTION ON AN EXCESSIVELY-USED HIKING TRAIL

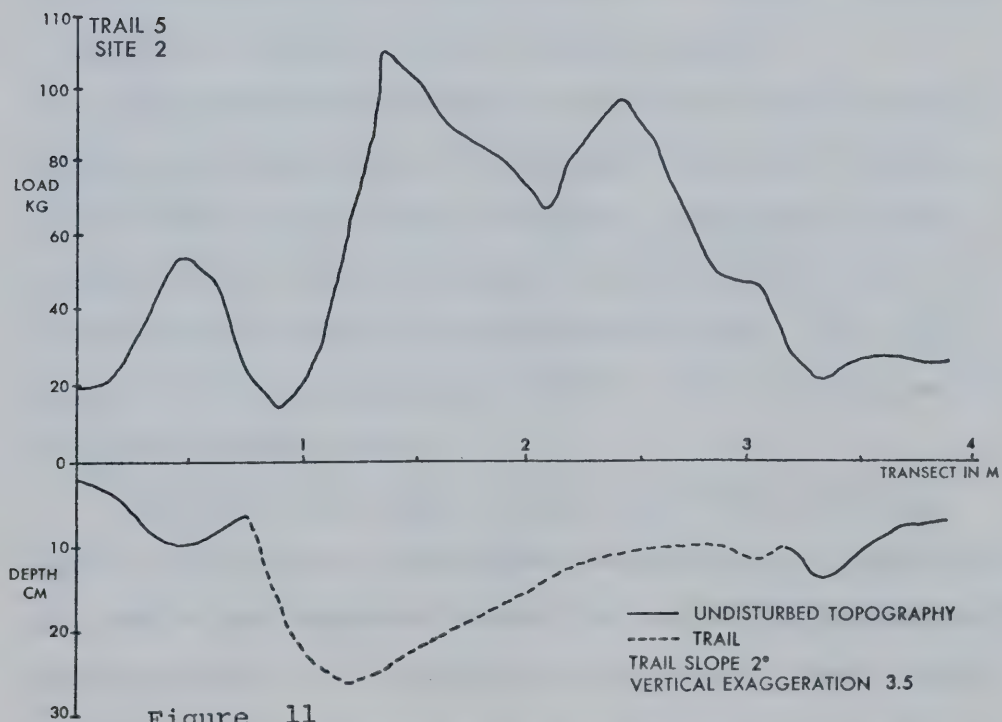
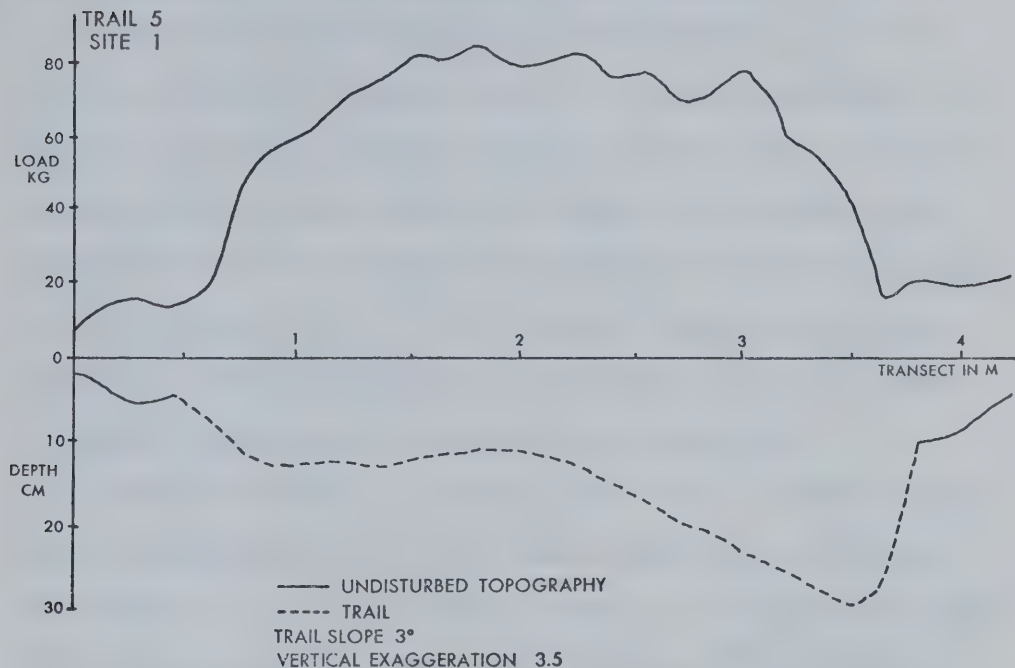


Figure 11

4.9 COMPARISON OF HIKING AND RIDING TRAILS

The different effects of hiker and horse use of a trail of equal or similar slope are shown graphically in Figure 12. The varying effects of both types of use on trails of different degrees of slope, at different elevations, and in a variety of vegetation zones have already been discussed. But, if one or more variables are kept constant, then differences in the impact of use on the remaining factors may be more easily observed.

Site 6 on Trail 2 and Site 4 on Trail 3 were chosen for illustration because of their similarity in slope; the former, on a hiking trail slopes at 17° and the latter, on a horse trail, at 18° . Both trails at these points are well-drained, away from springs or streams, and under a vegetation canopy with a 55 percent cover.

The cross-section at this site on the horse trail is narrower than the site on the hiking trail, the incision deeper, and the soil less compacted. Generally, as the slope of horse trails lessens, the soil compacts to a greater extent until the trail becomes level. The soil compaction on a level riding trail is just as great as that on a level hiking trail.

Observation was made of trail conditions changing with a change in use from riding to hiking. An example was the sudden and intensive pedestrian use of the predominantly equestrian Trail 4. Results of measurements taken one day before and one day after a site was passed by 110 hikers

COMPARISON OF EFFECTS OF HIKERS AND HORSES ON TRAIL SITES OF EQUAL SLOPE

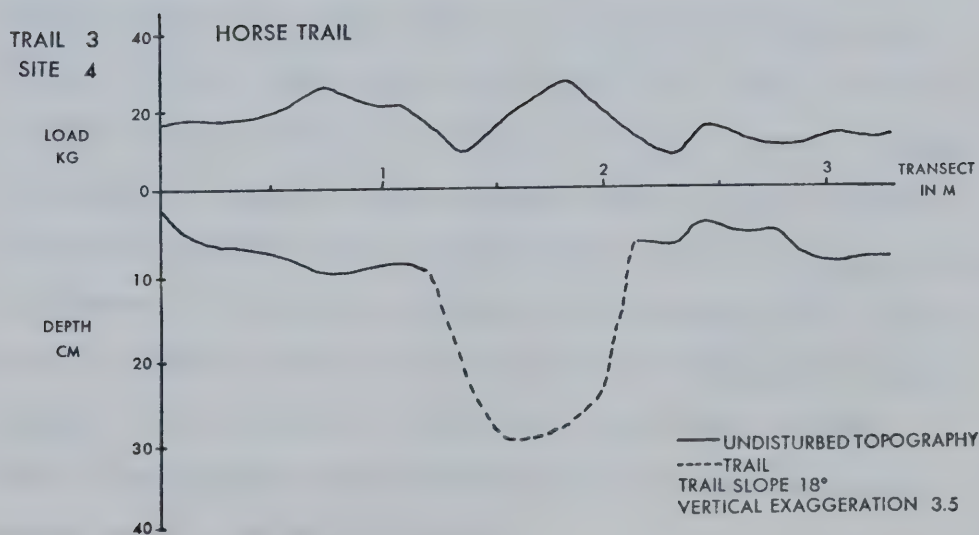
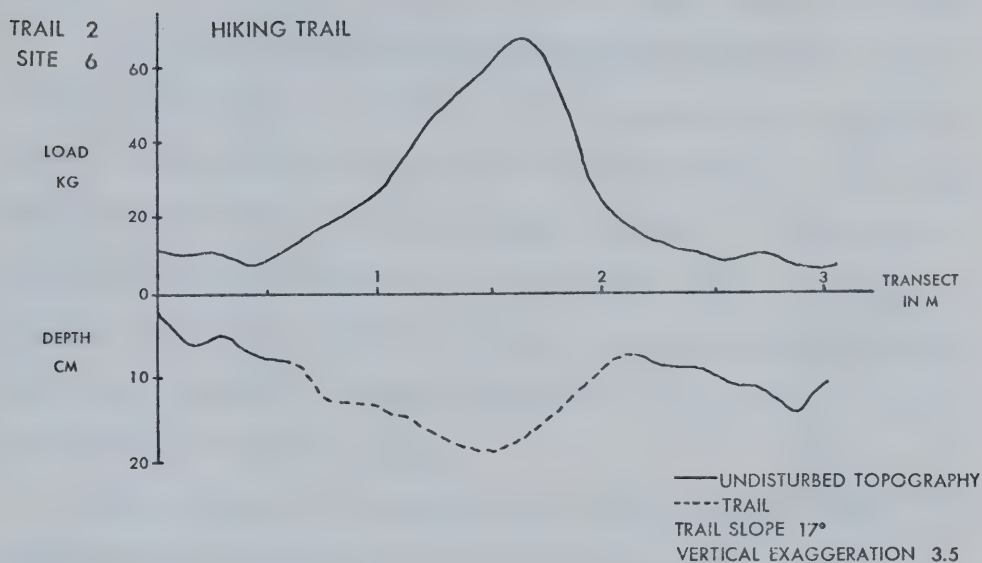


Figure 12

are shown on Figure 13. Up until this event the site had received only horse traffic during the season. The difference in compaction after horse and hiker use is obvious.

The high soil density on footpaths could be a result of the action of the human foot as compared to a horse's hoof. Humans pivot on the sole of their shoe as the body moves forward and the foot twists slightly. This action grinds and compacts the soil with every step. Horses simply move their feet up and down, their hooves punch the soil and break it up, particularly on slopes where slight or extreme slipping occurs.

The margins of an animal trail are sharply defined as compared to a footpath. Trail-side vegetation is usually trampled by hikers who do not keep to the path. The margins alongside a horse trail are clean-cut and there is no gradual merging into the surrounds. If horses are on a track of their own free will or are being led along in a saddle or pack train, they will stay on it. But, if driven by fear or are rushing to a definite object, food or water for example, they will not use the track. Left to their own devices, horses will follow along a trail in single file to pasture. When being rounded up and driven back to the barn by contrast, they will run from all directions cross country. That horses do not follow the trail on their return from pasture was substantiated by observations of tracks usually heading up-trail.

SOIL COMPACTION BY HIKERS ON A HORSE TRAIL

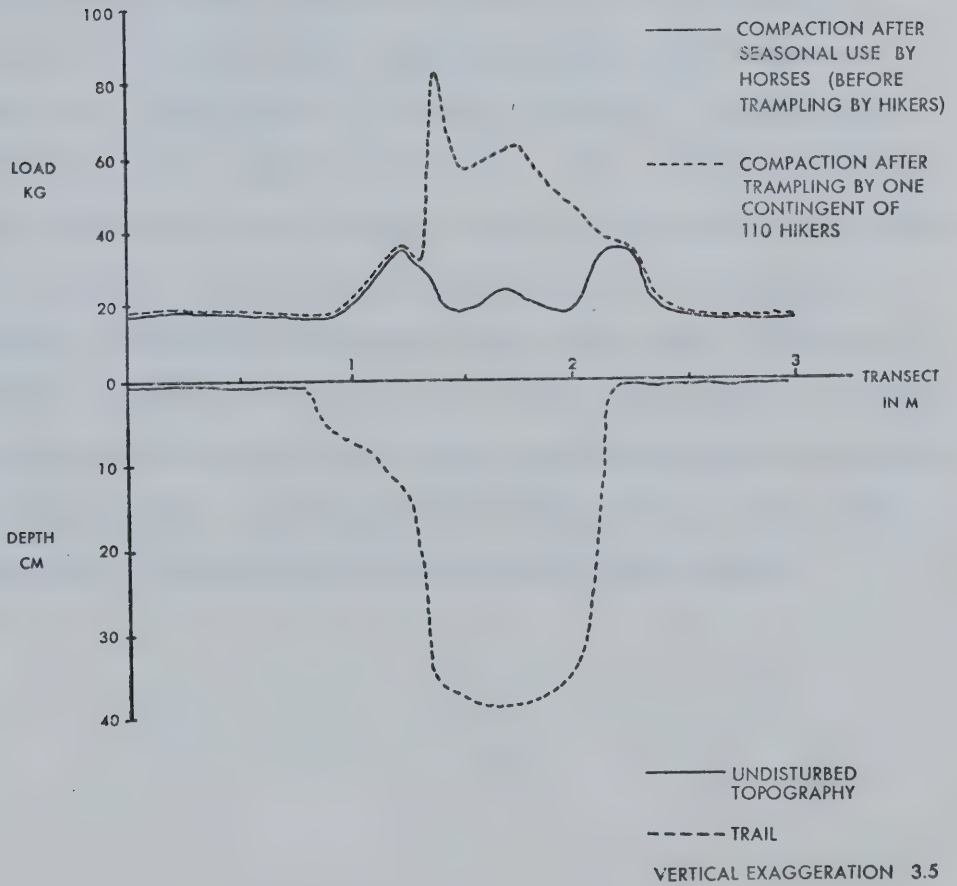
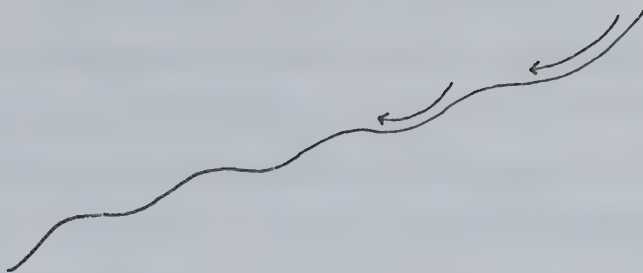
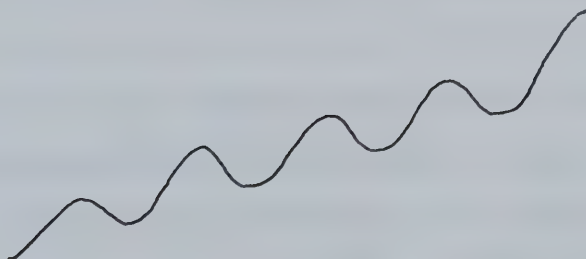


Figure 13

On some heavily-trodden sections of horse trails the earth forms into corduroy-like ridges. These average some 0.8 m in width and 0.3 m in breadth. They are generally rounded with fairly flat tops and steep sides. The furrows between them are deep and narrow much like waves. These ridges were found only where there was a slope, however slight, and at any elevation. They were observed on Trail 1 on a steep bank approaching Drystone Creek where the soil was thick and damp. Another example was found on Trail 4 at about 1890 m on a dry, gravelly, exposed site where the trail sloped at about 8° . The ridges seemed to form initially in wet weather when mud develops in a series of ridges and depressions perhaps because of microtopography, a slightly undulating area being more conducive to puddles forming in hollows. Mud pushed or dragged downhill as animals' feet slip into the hollows accentuates the depth of the furrows. As the furrows become deeper, they are unavoidable, so continued use increases their depth.



Horses' hooves naturally slip into wet hollows. A series of ridges forms parallel to the trend of the pathway.



Increased use accentuates hollows and forms a series of ridges.

Figure 14

Development of Trail Ridges

CHAPTER 5

CONCLUSIONS AND APPLICATIONS

Both pedestrian and equestrian traffic have effects on a trail other than dimensional. Because of trampling, damage to trail-side vegetation, littering, and misused campsites, the trail is often degraded aesthetically. With increased use of the trail, the path becomes unpleasant to users not only because of increased alteration, but because of the loss of the wilderness appeal. This appeal is lessened by the increasing numbers of hikers and riders in the back-country.

From observations of trail alterations, and an accurate determination of the number of trail users, it should be possible to assume a use-capacity for each trail. If this were done for all the mountain and foothill trails in west-central Alberta and Jasper National Park, a useful trail management system could be developed. Areas in which the number of users has detracted from the quality of the area, or trails which cannot physically or ecologically entertain high-intensity use could have their number of users lessened. Conversely, those trails rarely used but having a high capacity for use, or areas not yet traversed by trails but of suitable scenic, locational, and ecological characteristics, could be opened and publicized. A properly planned use program should be followed in order to more evenly distribute the hiking and riding trail use. This would render some areas more pleasant and, at the same time,

utilize some beautiful and practical, yet seldom-used portions of the mountain zone.

5.1 CARRYING CAPACITY

The recreational carrying capacity of an area is the amount and character of use that can be supported over a specific time and at a certain level without damaging either the physical and biological resource or visitor satisfaction. Thus, carrying capacity is a multidimensional concept comprising recreational impact on the resource base, visitor behaviour and attitudes, and management objectives. The main goal of recreation site management is to maximize visitor use and satisfaction within the constraints of the resource base, budget, and administration.

5.2 TRAIL LAY-OUT TO REDUCE IMPACT ON THE RESOURCE BASE

Any use or stress placed on an ecosystem will result in some physical change. Unrestricted recreational use of mountain hiking and riding trails will eventually lead to soil compaction, increased erosion, alteration of presence and composition of plant species, and a dissatisfaction among visitors.

One method of reducing damage to the trail environment would be to modify or "harden" the site or area making it less susceptible to degradation by heavy foot or horse traffic. The durability of the adjacent plant community could be increased and the site made more resistant to

change by a number of methods. Some alterations are: fertilization, irrigation, aeration, reseeding, introduction of hardy species, and paving of paths.

However, the introduction of an artificial remedy would create a change in the natural setting, and defeat the reason for that area's use. Instead of hardening an area, degradation should be reduced through improved methods of trail lay-out, visitor education, and trail management.

An imaginative yet studied method of site design, landscaping, and trail engineering could effectively reduce trail damage while increasing carrying capacity. The channelling of visitors into areas previously underused would distribute recreational use and reduce the stress on the popular and overused trails in the mountain regions.

If the movements of recreationists on trails were guided, then fragile portions of trails could be lightly used or avoided. By making most use of the least alterable trail environments, hikers and riders could maximize their enjoyment and render least damage to the area.

Damage to ground cover and erosion of a trail occurs not only because of direct bruising and crushing of vegetation, but also because of soil compaction or removal due to trampling. Once a substantial amount of protective plant cover and litter has been removed, hikers tend to severely compact the soil thereby reducing the available soil moisture and air needed by underlying plant roots. Severe

compaction reduces or eliminates the chances for revegetation along the trail. Such highly intensive use as that received by popular trails to view points has resulted in soil compaction to such a degree that penetration by recording instruments was difficult or impossible.

This is the case on trails along Maligne Canyon, at Miette Hot Springs, on portions of the Astoria River Trail below timberline, and, to some extent, on Trail 2 at Folding Mountain.

A main agent of trail soil erosion is running water. The removal of vegetation and the deepening of a trail create a natural channel for water. This effect is most important on inclined trails and in areas near springs or snow banks. To reduce the effects of running water, trails should not be constructed to run straight uphill.

Damage to trails is excessive in swampy or wet areas. Horse traffic especially softens wet ground and subsequent traffic widens the trail by travelling along the higher or drier trail banks. If swamps, springs, stream edges, or snow bank verges cannot be avoided, they should be set with corduroy planks or traversed by a raised platform or bridge. Trails should be located along well-drained and exposed south or west-facing slopes as much as possible to maintain a dry soil.

Switchbacks are most susceptible to erosion by running water and by hikers and horses cutting the corners and travelling straight up or downhill between trails. Guard

rails, boulders, or logs could be used to direct traffic and small, rustic directional signs may keep people on the trail. This method could also be used to keep traffic from shortcutting through fragile areas on level trails.

Mechanized trail vehicles are not only incompatible with foot travel, but considerably add to plant damage, soil erosion, and noise pollution. Trail bikes, skidoos, and jeeps should be restricted to roadways or specially designated areas.

Hiker and horse use of trails can be compatible depending upon the area. Level uplands and rocky areas show least signs of damage resulting from trail use. However, low-lying or wet areas are greatly altered, especially by horses. In heavily used, fine-soiled, steep, or wet areas, horses should be kept apart from hikers. Stream beds are easily followed by horses and, since many mountain trails parallel streams or rivers, some paths could be used by horses along gravel bars and through shallow water. Since equestrian traffic is unpleasant to hikers, promotes erosion and even accidents, any necessary horse use should be restricted to one trail and then only after mid-July at which time the trails should be dry.

In areas used intensively for guided nature walks, it would be beneficial to pave trails with wood chips or even asphalt. Visitors do not venture off a paved trail as readily as off a natural path. Although the natural setting would be altered somewhat, at least traffic would

be restricted to the path and alteration of the surroundings would be minimized.

5.3 TRAIL MANAGEMENT

The management of a trail system depends upon the physical resource, demand, and the specific goals of the area. Physical improvements or additions are made according to the capacity of the area, but visitors' behaviour causes degradation, so restrictions or education must be placed upon the human factor of trail placement and management.

Visitor use can be channelled depending upon the needs and abilities of the hiker. An efficient trail information service would ensure a distribution of use such that rarely-used yet easily traversed and accessible areas were utilized thereby reducing the excessive use on some trails. Presently in Jasper National Park the information service is ill-equipped to advise tourists on any more than two of the scores of park trails. Because of this lack of information, the Signal Mountain and Astoria-Tonquin Trails are vastly overused while trails such as the Poboktan, Fryatt, and Snake Indian are underused. An improved service could effect a trail use rotation system which could channel use into areas accessible and dry early in the summer season and those suitable for intensive summer use. This rotation could be used on a yearly basis to leave an area to recover for a season before use is resumed.

Communicative and interpretive services would inform trail users of the length of trail, degree of difficulty, time needed, and facilities provided. Signposts, pamphlets, directional arrows, and guide services would increase the knowledge of trail users and perhaps limit the degree of damage, littering, and overuse.

Fees, reservations, or eligibility requirements may further help to distribute use. Regulatory procedures such as these would ensure the desire or capability of the back-country traveller whose use and appreciation of mountain trails greatly determines the resultant damage or change of an area. Zoning of mountain trails for specific types or periods of use could be considered. Under a system of time zoning, a certain number of people would be allowed into an area for a given length of time, or an area would be open to hikers only during certain times of the year. The optimum season for use of trails in the Rocky Mountains, Alberta, would be July, August, and early September after snow melt on the high alpine meadows. Trails would be dry and less susceptible to damage than during May and June. Trails could be closed during particularly wet weather. Limits on party size could further distribute recreational use thereby increasing carrying capacity.

Efficient management of trails is a combination of proper trail engineering, restrictions on excessive or destructive use, education of travellers to reduce des-

tructive behaviour, and a liason between trail users, managers, and researchers.

5.4 LEGISLATION AND EDUCATION

Proper management coupled with maximum enjoyment of trail use in National Parks can be achieved only through an adequate public education program. If park users were more informed about the role of National Parks, the physical, biological, and aesthetic effects of misuse and overuse, and the beneficial implications of resource conservation, then the task of management might be lessened.

Presently, the virtues of Alberta's Rocky Mountains are being extolled in an international campaign to attract visitors. Such advertising draws thousands who crowd, trample, and litter an environment which has been set aside for the purpose of preserving a vestige of the natural world. A great amount of energy plus large sums of money are put into this advertisement. These expenditures could better go toward promotion of conservation and a comprehensive program for public awareness and education.

Educating park users about their role in maintaining the environment in a state of least inpairment can be carried out at different levels. Large-scale programs could begin with federal assistance and the use of national news media. Rather than appealing for greater use of park areas, news releases and television or radio documentaries could discuss the fragility of the mountain parks. Proper

use of wilderness areas and the curtailment of depreciative behaviour should be reported. Nature films should stress points of environmental conservation rather than imply them. Federal legislation could be implemented to provide, develop, and advertise areas outside nature reserves. These areas, many of which are less susceptible to environmental degradation, could contain visitor service centres and recreation sites.

At a more local level, municipal agencies can provide many public services to increase awareness of the individual's role in resource conservation. Pre-tourist season courses on back-country travel which review park purposes and use restrictions could be made available. This, together with increase in the number of the already existing programs on techniques of and equipment for hiking, climbing, and ski-touring would not only increase an awareness of the environmental problems associated with park use, but also decrease many of the hazards of wilderness travel that result from inexperience or ignorance.

Many on-site methods could be employed to inform visitors of the potential of man to damage his surroundings. Information provided within Parks would be the most beneficial type of public education. Park information centres should be staffed by knowledgeable personnel who not only hand out pamphlets in local sights, but who also can disseminate facts on the area's fragility and vulnerability to human pressures. Popular centres within the parks

should all provide nature walks and presentations by naturalists on the human carrying capacity of the area.

A system of manned or unmanned checking stations at all major trailheads could prove beneficial in regulating back-country use. Scrutiny by a park official over all equipment taken along the trails would help limit damage and garbage left in the parks. Re-checking packs after hikers return to the trailhead would help ensure that all back-country travellers pack out their garbage. Another means of reducing damage to the high country is to limit access into rigorous areas to those physically fit, skilled in wilderness travel, and suitably outfitted.

Directional signs at all trailheads could be supplemented with information about trail length, difficulty of the hike, and statements about the nature or fragility of the terrain and the trail condition. Warnings against removal of plants or rocks, chopping trees, and littering, along with a listing of fines levied for any depreciative acts within the parks may serve to lessen intentional damage along mountain trails.

In order to ensure the public's maximum enjoyment of mountain areas and National Parks as well as minimum damage to the environment, it is essential that the visitors be suitably educated. Public awareness of the individual's responsibility in helping maintain a balance between use and conservation resources must be brought about through comprehensive education programs and modified

government legislation. The awareness of park and wilderness users is a major determining factor in the effective management and conservation of the resource base.

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